The Llandovery Series of the Type Area

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Contents

Bull. Br. Mus. nat. Hist. (Geol.) **38** (3): 131–182

Issued 29 November 1984

Synopsis

The stratigraphy, fossils and correlation of the Llandovery area, Dyfed, Wales, are reviewed and its status assessed as the international type area for the lowest series of the Silurian System. A new lithostratigraphy is described, based on fresh mapping and exposures, of the Tridwr and Scrach Formations of Ashgill age, and of the Bronydd, Crychan and Trefawr Formations in the northern part of the Llandovery area, with the laterally equivalent Coldbrook and Goleugoed Formations in the central and southern parts of the area. Above these come the Rhydings, Wormwood and Cerig Formations, and the Wenlock age Gwernfelen Formation. The Derwyddon Formation is the lateral equivalent of the Rhydings and Wormwood Formations in the Pen-y-waun fault belt in the north-east.

The distributions of the major faunal elements are assessed and many new fossil records from the area noted, particularly of graptolites. A *Hirnantia* fauna is reported from the Scrach Formation. The stage divisions within the Llandovery Series are revised, with new faunas from the Rhuddanian Stage. The base of a new Aeronian Stage is defined within the Trefawr Formation at the base of the *triangulatus* Zone, and the base of the overlying Telychian Stage is redefined upwards and placed above the last record of *Eocoelia intermedia*, near the top of the Wormwood Formation, a horizon which approximately correlates with the base of the *turriculatus* Zone. The international correlation of the three stages is discussed.

Introduction

In 1977 the Silurian Subcommission of the International Union of Geological Sciences established in a postal vote that the term 'Llandovery' should be used for the lowest series of the Silurian System, following more than a century of usage. However, in 1979, during a field excursion to Britain, several members of the Subcommission were dissatisfied with the Llandovery area, Dyfed, Wales, as a type area, partly because some of the boundaries of the previously-defined stages (Cocks *et al.* 1970) were in isolated outcrops rather than in continuous sections, and partly because these stage boundaries had not been defined accurately enough in biostratigraphical terms. In addition the stratigraphy of the southern part of the Llandovery area had not been revised for over fifty years (Jones 1925). Accordingly, a small group was asked by the Subcommission to reinvestigate the whole Llandovery area, both north and south, and this is their report. The field work was done together in several periods from 1979 to 1983: N. H. Woodcock is primarily responsible for the lithostratigraphy and mapping, R. B. Rickards for work on the graptolites, J. T. Temple and L. R. M. Cocks for the earlier and later Llandovery brachiopods respectively, P. D. Lane for the trilobites and L. R. M. Cocks for coordinating the project.

This revision is opportune for several reasons, for example because the Forestry Commission has created several kilometres of continuous exposure in new forestry tracks in the area, which we have been able to evaluate, and also because research work over the past twenty years on rocks of Llandovery age, both in other parts of Britain and elsewhere, has led to a large new reservoir of knowledge on shelly, graptolitic and other faunas, many of which have been found in abundance in the present study. We have completely remapped the area, established a new lithostratigraphy (Fig. 1) and a new chronostratigraphy, and integrated these with the established international biostratigraphy. We conclude that the Llandovery area is fully suitable to continue as the international standard for the lowest series of the Silurian System.

History of Geological Studies in the Type Llandovery area

The Llandovery district has long been the standard British and international reference area for rocks of what are now termed Lower Silurian age. R. I. Murchison published his classic 'Silurian System' in 1839, in which there are five closely-printed pages (pp. 350–355), a general view (fig. 66) and two coloured geological sections (pl. 34, figs 1 and 3) describing the results of his three visits to the Llandovery district in 1833, 1834 and 1835. In Part II of the work, 'Organic Remains', Murchison himself and his colleagues J. de C. Sowerby,

JONES (1925) SOUTHERN "Wenlock"	JONES (1949) NORTHERN "Wenlock"	NEW TERMINOLOGY NORTHERN Gwernfelen Fm	CENTRAL Gwernfelen Fm	SOUTHERN Gwernfelen Fm
C_6				
C_5	Cc	Cerig Fm	Cerig Fm	Cerig Fm
C_4	Cb	Wormwood Fm	Wormwood Fm	Wormwood Fm
C_3				
C_2	Ca	Rhydings Fm	Rhydings Fm	Rhydings Fm
C_1				
B_3				
B_2	B	Trefawr Fm	Coldbrook Fm	Goleugoed Fm
B_1				
A_4	Ac	Crychan Fm		
A_3				
A_2	Ab	Bronydd Fm		
A_1 / Aa		Scrach Fm	Scrach Fm	Scrach Fm
"Bala"	"Bala"	Tridwr Fm	Tridwr Fm	Tridwr Fm

Fig. 1 New lithostratigraphical terminology compared with those of Jones (1925) for the southern Llandovery area and Jones (1949) for the northern Llandovery area. The Tridwr and Scrach Formations are of Ashgill age and the Gwernfelen Formation is of Wenlock age.

Lonsdale and others described and illustrated twenty species of brachiopods, three gastropods, four nautiloids, a trilobite and two corals from the type Llandovery area (plus others from the overlying beds of Wenlock age at Llandovery). Although Murchison initially miscorrelated these 'Llandovery Building Stones' with the Caradoc of Shropshire, this error was corrected after the work of Sedgwick, Aveline, Ramsay and Salter, who between 1852 and 1854 (e.g. Salter & Aveline 1854) established the existence of an unconformity in

Shropshire between what is now known as the Silurian and the underlying rocks. These post-Caradoc, sub-Wenlock rocks were initially termed 'May Hill Rocks', but it was quickly realized that the rocks at May Hill, Gloucestershire, correlated only with the upper part of the sequence present at Llandovery, which was being mapped more precisely by W. T. Aveline for the Geological Survey in 1855–6. Thus the Geological Survey maps of 1857 were the first publications to use the term 'Llandovery' (divided into Upper Llandovery and Lower Llandovery) in a time-stratigraphical sense. Since Murchison was intimately associated with the Government surveyors (and himself joined the Geological Survey as Director-General in 1855), it was no surprise that he adopted the Survey terminology in a variety of papers, for example that on the Oslo region in Norway (1858), and in a revised edition of 'Siluria' (1859). Henceforth, the Llandovery became, and has remained, the standard for the lower part of what is now the restricted Silurian System both in Britain and elsewhere, and it is notable that Lapworth (1879: 14) in his original definition of the Ordovician System took it up to 'the base . . . of the Lower Llandovery.'

The first major revision of the Llandovery area after Aveline and Murchison was that by O. T. Jones, who mapped the area from 1915 onwards. He published this revision in two parts, the first paper on the southern half of the area (1925), and the second on the northern half (1949). In his first paper he divided the old Lower Llandovery into two parts, called Lower and Middle, separated by what he identified as an unconformity, and he established a series of divisions labelled A_1 to A_4 for the Lower Llandovery, B_1 to B_3 for the Middle Llandovery and C_1 to C_6 for the Upper Llandovery (Fig. 1). However, Jones had problems in extending these lithostratigraphical divisions over the area as a whole, and when he eventually published on the northern half of the Llandovery area (1949), he divided the Lower Llandovery there into Aa, Ab and Ac and the Upper Llandovery into Ca, Cb and Cc, with an undivided Middle Llandovery.

Although Jones (1928) had published on the plectambonitaceans from the area, the main part of his brachiopod collections was studied by A. Williams, who published what has become a classic paper (1951), with formal descriptions of 39 taxa and records of 86 different brachiopod species and subspecies, including the first account of the evolution of *Stricklandia*. Subsequent to Williams' work, the previously-defined lithostratigraphical units of Jones (C_1 etc.) have been employed as biostratigraphical subzones, and used as standard correlation units for the world as a whole (e.g. Berry & Boucot 1970 for North America). From a desire to attain more uniform terminology, such as that employed elsewhere in the Lower Palaeozoic, Cocks *et al.* (1970) divided Llandovery time into four stages, each with a base defined in the southern part of the Llandovery type area, apart from the basal stage, the Rhuddanian, which was taken from the base of the *persculptus* graptolite zone at Dob's Linn, Scotland. These stages were used as standard in the Geological Society's correlation chart of the Silurian rocks of the British Isles (Cocks *et al.* 1971).

A substantial number of publications in the last thirty years have described one or more fossil species each from the type Llandovery area; some of these papers are detailed below in the section on biostratigraphy, but until now there have been no other stratigraphical revisions of the area, apart from the unpublished sedimentological study by M. A. Woollands (1970) and short field guides (e.g. Cocks 1971). Woollands established that Jones had been mistaken in identifying an unconformity beneath his Middle Llandovery.

Lithostratigraphy

A formal lithostratigraphy is established here for the Llandovery Series rocks and some adjacent units, based on mapping and on measured lithological logs. The outcrop pattern of the new formations is shown in Figs 2 and 3 and their mutual relations in a south-west to north-east section in Figs 4 and 68 (p. 172). Many of the formation boundaries correspond closely to contacts mapped by Jones (1925, 1949) and Woollands (1970). However, we have subdivided the sequence less than they did, without formal recognition of those subtle lithological distinctions which cannot be mapped for more than a kilometre or so.

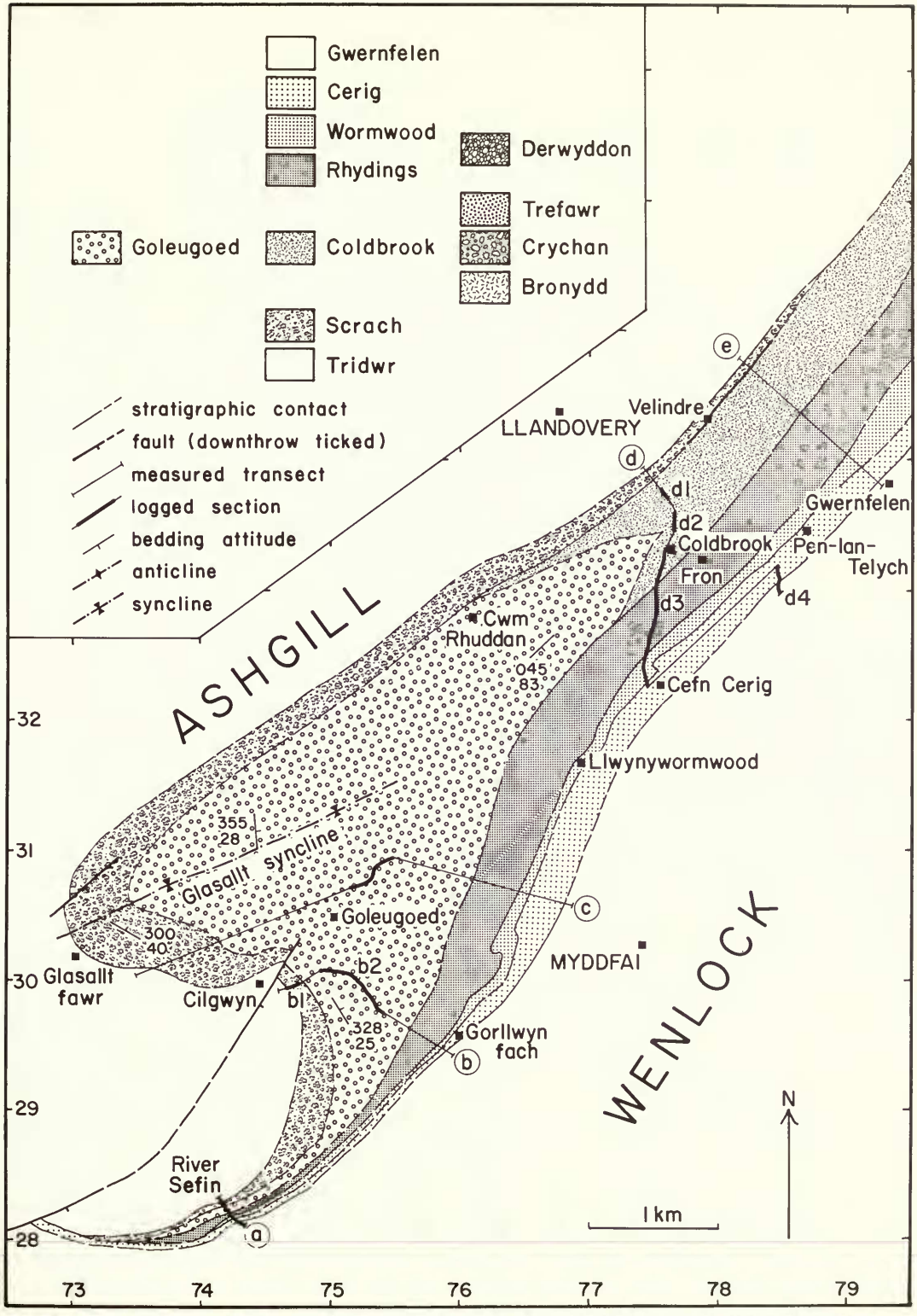


Fig. 2 Geological map of the southern part of the Llandovery area, showing transects a to e. The measured parts of the transects are shown as thicker lines; the thinner lines link the appropriate measured sections to the total transects shown on Fig. 4, pp. 138–9. The numbered 1 km squares of the National Grid are shown: they all fall within the SN 100 km square.

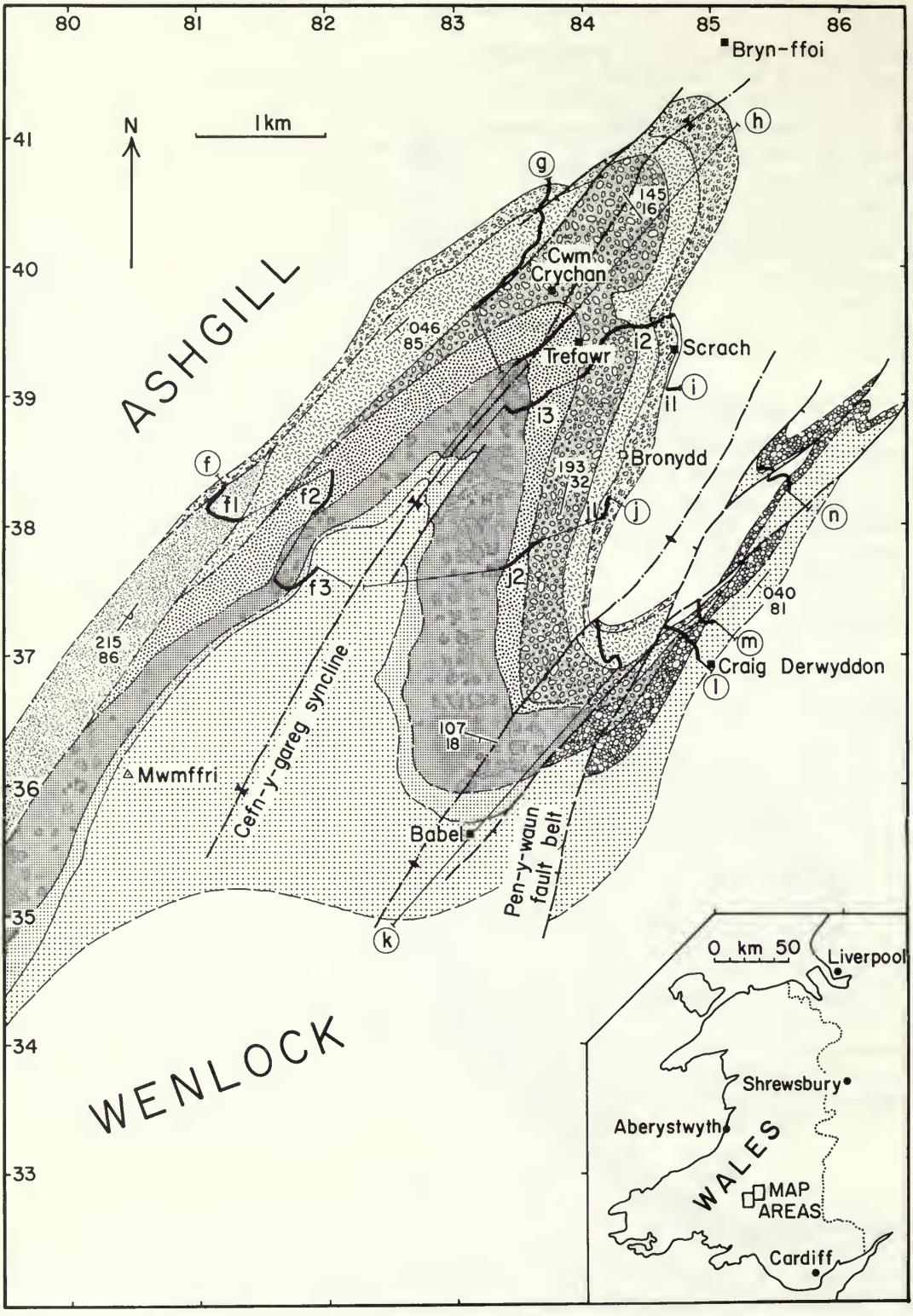


Fig. 3 Geological map of the northern part of the Llandovery area showing transects f to n. The key to the ornament is on Fig. 2.

We confirm the view of Woollands (1970) that the only angular unconformity in the Llandovery Series is that below Jones' Upper Llandovery. Even at this level there is apparently a conformable sequence everywhere except in the Pen-y-Waun fault belt and the possible continuation of the fault belt in the extreme south-west of the area (Figs 2–4). In particular, the new biostratigraphic control suggests that a full sequence may be present below the later Llandovery rocks in the central steeply-dipping belt near Llandovery itself (transects d and f in Fig. 4). The lateral variability in Jones' Lower and Middle Llandovery is therefore due to true lateral facies changes (Woollands 1970) and not to overstep (Jones 1925, 1949).

The formations are described and interpreted below approximately in order from oldest to youngest, with reference to the lithological logs in Fig. 4. Lithological details shown in Fig. 5 are not repeated here. Interpretations of the facies are based on those of Woollands (1970), with major modification only in the case of the Scrach Formation.

The *Tridwr Formation* is typified by the mudstones of Ordovician age in the core of the Noethgrug Anticline, south-east of Bronydd (Fig. 3). Here the mudstones commonly have intercalated shelly sandstones (e.g. transect i). Elsewhere in the area (e.g. transects a, g) the Ordovician mudstones at this level rarely contain sandstones and these sequences are only tentatively assigned to the Tridwr Formation. Along the northwestern boundary of the area, the mudstones have a strong planar fabric, mainly a tectonic cleavage. The Tridwr Formation probably represents mud-dominated deposition on a marine shelf. Occasional strong traction currents, probably storm-generated, produced winnowed sands, particularly near the south-east margin of the area.

The *Scrach Formation* is dominated by shales with numerous thin ripple-cross-laminated sandstones. Occasionally (e.g. transect g) the sandstone layers comprise the bulk of the rock. In two areas (transects c, h) thick sandstone/conglomerate lenses occur within the typical Scrach facies; these latter are the 'basal Llandovery sandstones' (A_1, A_a) of Jones (1925, 1949). Our new data suggest that the Scrach Formation is latest Ordovician (Hirnantian) in age. The lenticular or flaser bedded lithology is characteristic of shallow sub-tidal or in part even intertidal conditions. The coarse sand bodies might represent tidal bars or channels. The undoubted shallowing compared with the Tridwr Formation is thought to reflect the late Ordovician glacio-eustatic lowering of sea level (cf. Brenchley & Newall 1980).

The *Bronydd Formation* mainly comprises mudstones completely lacking lamination or even bioturbation structures. There are sporadic thin micaceous shelly sandstones, weathering to 'rottenstones'. The base of the formation where seen (transects g, i, k, l, m) is always an abrupt conformable contact with the Scrach Formation, usually with a tough siltstone immediately above the contact. The sand content increases up the section both as discrete sandstones and as dispersed grains in the mudstones. The Bronydd Formation represents mud-dominated deposition on a marine shelf with occasional storm events generating discrete sand beds. The sharp base of the formation may mark the rapid sea level rise subsequent to the latest Ordovician glacial event (Brenchley & Newall 1980). The coarsening-up sequence suggests a prograding sedimentation system, probably pro-deltaic.

The *Crychan Formation* is dominated by massive, poorly sorted muddy sandstones, always bioturbated and commonly containing dispersed pebbles. Occasional well-sorted sandstone beds occur, thinner than in the Bronydd Formation. The boundary with the Bronydd is gradational over 10 m or so (e.g. transect i). The Crychan Formation thins and fines down the north-west limb of the Cefn-y-gareg syncline. The Formation probably represents deposition on a more proximal part of a pro-delta lobe than the Bronydd Formation, but still in fully marine conditions. The sediment source was from the south-east. Traction currents were strong enough at times to roll pebbles across a cohesive mud substrate, and occasional storm events left thin winnowed sand beds.

The *Trefawr Formation* is rather varied, but is typically finer grained than the underlying Crychan Formation (e.g. transects i2 and i3). The dominant lithology is unlaminated sandy

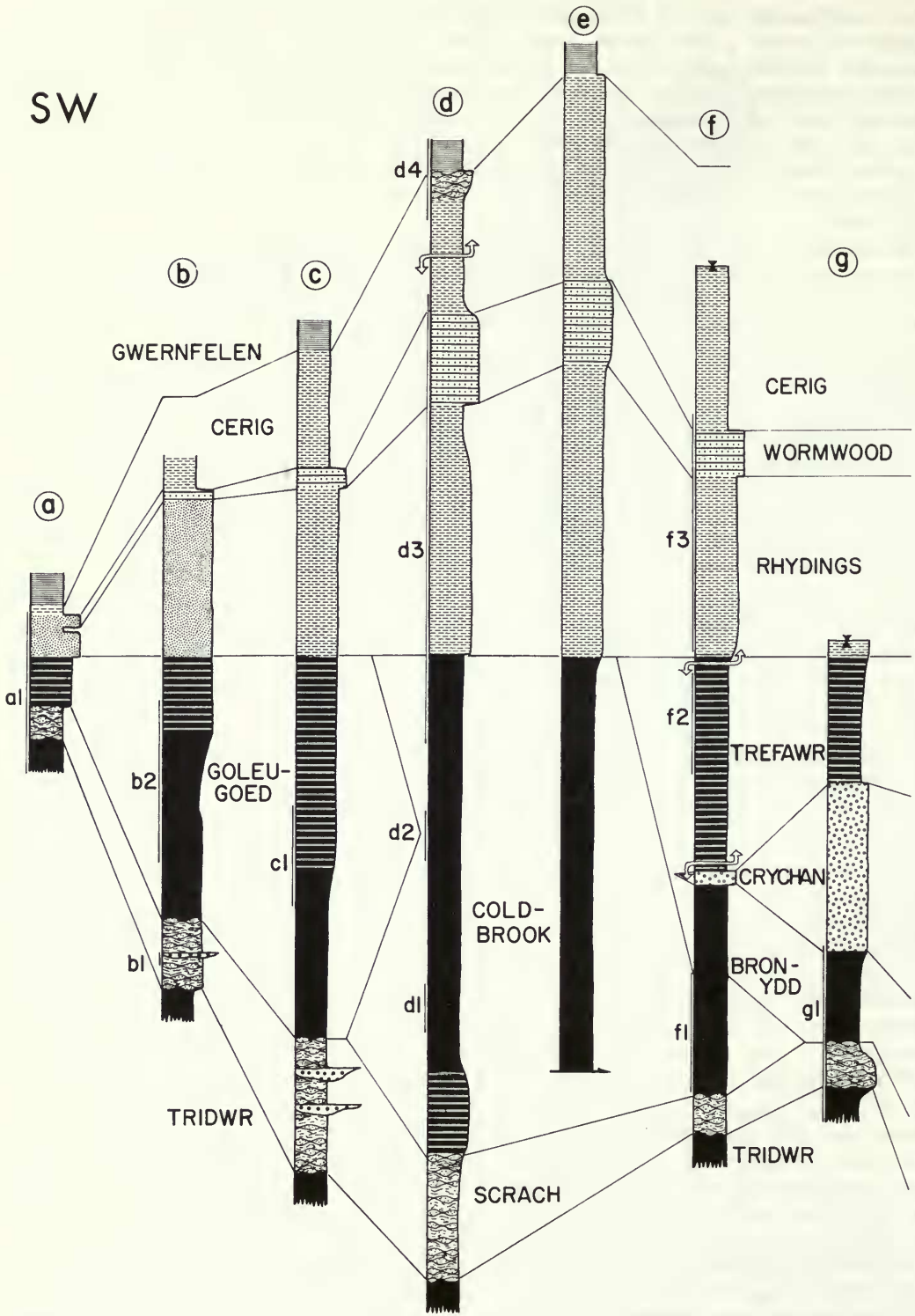
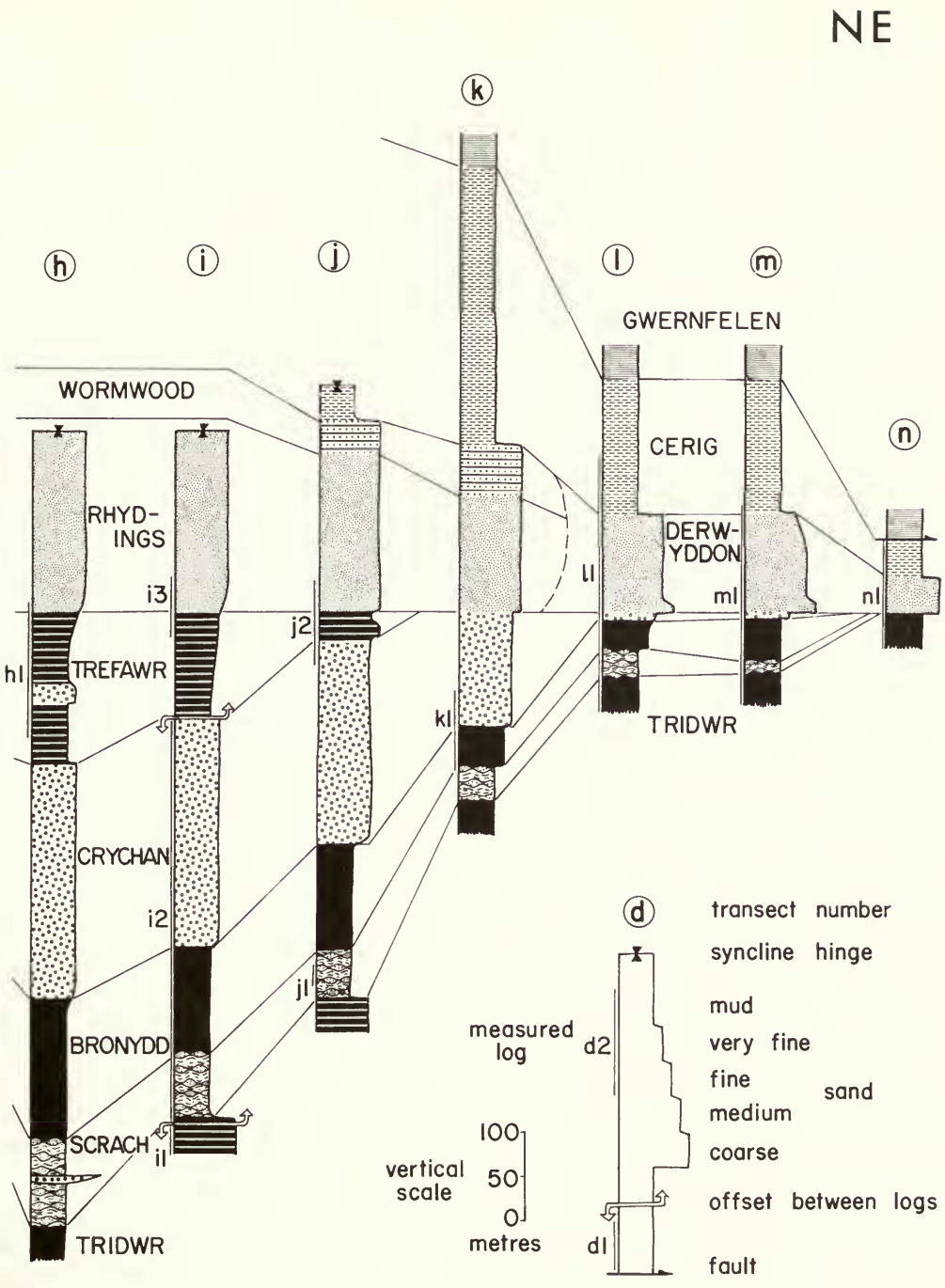


Fig. 4 Transects a to n south-west to north-east across the type Llandovery area. The key to the ornament is shown on Fig. 5, p. 141. The vertical lines on the left of the various transects show the position of the continuously exposed and measured parts of the transects. The locations of



the transects are shown on Figs 2 and 3 and the grid references of the ends of the measured sections are given in Appendix 3, p. 178.

mudstone similar to the Bronydd Formation but including more frequent micaceous calcareous sandstone beds. The formation generally coarsens up the section. Sandy mudstones with dispersed pebbles occur in the central part of the sequence in transect h (Figs 61, 62) and dominate the Trefawr Formation in the south-east (transect k). The Trefawr Formation, like the Crychan, fines on the north-west limb of the Cefn-y-gareg syncline (Fig. 3). Interpreted as a pro-delta marine sequence, the Trefawr represents more distal conditions than the underlying Crychan Formation, probably because of a lateral switch in the sediment supply. Probable storm sands were again produced.

The *Coldbrook Formation* is the lateral equivalent of the Bronydd, Crychan and Trefawr Formations in the central part of the Llandovery area, south-westwards of where the Crychan Formation thins to zero and fails to differentiate the finer Bronydd and Trefawr Formations. The Coldbrook comprises silty mudstones, often fissile owing to an imposed slaty cleavage. In transect e the stratigraphically highest parts of the Coldbrook are unlaminated, whereas lower parts are laminated with thin, parallel-laminated sandstones. Occasional thicker calcareous sandstone beds occur, and are locally abundant in the basal 100 m near transect d. These vertical variations cannot be mapped far along the strike. The Coldbrook Formation presumably represents marine clastic deposition further from the sediment supply than areas to the north-east and south-west. However, the total sediment thickness was not reduced (Fig. 4). High energy conditions occurred locally during deposition of the lowest part of the Formation.

The *Goleugoed Formation* is the lateral equivalent of the Coldbrook Formation in the south-west part of the Llandovery area. It is again dominated by mudstones, but includes a much higher proportion of thin sandstone beds and of dispersed sand than the Coldbrook. The average grain size and frequency of sand beds tends to increase up the section and these form locally mappable boundaries in transects b and c. Above the well-exposed parts of these transects occur muddy sandstone intervals but poor exposure prevents their lateral correlation. The Goleugoed Formation represents shallow marine deposition closer to a sediment source than the Coldbrook Formation. A pro-deltaic environment is suggested by sequences coarsening upwards, similar to those in the Bronydd/Crychan and Trefawr Formations, though no direct lithological correlation with the north-west area can be made.

The *Rhydings Formation* is mappable from north-east to south-west of the Llandovery area as relatively resistant sandy mudstones or muddy sandstones. These sediments are moderately to well sorted and often parallel-laminated, in contrast to the sandy facies in, for example, the Crychan or Goleugoed Formations. The lower boundary of the Rhydings is conformable over much of its outcrop length and is often gradational (e.g. transects h, i and j). As an angular unconformity develops at this level towards the Pen-y-waun fault belt (Fig. 4), the Rhydings Formation becomes thinner and coarser, and passes laterally into the Derwyddon Formation described below. A similar transition is seen above the unconformity in the Sefin River section at the south-west end of the area. The Rhydings Formation records open marine shelf deposition resulting from the well-documented late Llandovery marine transgression (Ziegler, Cocks & McKerrow 1968). The transgressed sea-floor topography still influenced sedimentation (Woollands 1970) with coarser, presumably shallower facies deposited on the existing pro-delta lobes (e.g. transects h, i and j) and finer-grained facies in the interlobe area above the Coldbrook Formation (e.g. transects d, f).

The *Wormwood Formation* consists of muddy sandstones and calcareous mudstones, more thinly and better bedded than the Rhydings (Figs 65, 66), but with beds more intensely bioturbated. The Formation is best distinguished in the southern Llandovery area (e.g. transect d). It is recognizable further north-east (e.g. transect f), though it may not be continuous there. As with the underlying Rhydings Formation, it is replaced laterally by coarser facies in the Pen-y-waun fault belt and in the extreme south-west of the area. The Wormwood Formation may represent open marine shelf conditions slightly shallower than

FACIES SYMBOL	FORMATION	LITHOLOGY	RANGE OF GRAIN SIZE	SORTING	COLOUR	BEDDING THICKNESS	SEDIMENTARY STRUCTURES
	Gwernfelen	muddy siltstones or very fine sandstone	clay to vf sand	moderate	grey/black	max 1cm	very fine (1 to 5mm) parallel lamination
	Cerig Rhydings	silty or sandy mudstones	clay to vf sand	moderate	greenish grey	max 4cm	parallel lamination, some bioturbation, some granule layers
	Wormwood	muddy sandstones	clay to m sand	poor	dark green to dark grey	max 40cm	well bedded, but poorly laminated, strong bioturbation, shell layers
	Rhydings Derwyddon	sandstones or muddy sandstones	silt to vc sand	moderate /good	bluish or greenish grey	max 1m	parallel & cross lamination, ripples strong bioturbation, pebble layers
	Crychan Trefawr Goleugoed	pebbly muddy sandstones with some calcareous sandst's	clay to pebbles f to m sand	poor good	bluish or greenish grey bluish grey	0·5-2m max 3cm	bioturbated, dispersed pebbles parallel lamination
	Crychan Trefawr Bronydd Goleugoed Tridwr	sandy mudstones with some micaceous sandstones	clay to f sand f to m sand	moderate good	dark grey bluish grey	ave 1m max 30cm	bioturbated, occasionally parallel laminated. poorly laminated occasionally graded
	Coldbrook Bronydd Tridwr	silty mudstones with rare micaceous sandstones	clay or silt f to m sand	moderate moderate	dark grey light grey	ave 1m max 5cm	uniformly non-laminated (slaty in Coldbrook) poorly laminated occasionally graded
	Cerig Scrach	silty shales with thin sandstones	clay or silt vf to f sand	moderate good	dark grey greenish grey	ave 1cm ave 1cm	fissile ripple cross-lamination, surface trails.
	Scrach	sandstones / conglomerates	f sand to pebbles	good	greenish grey	ave 0·5cm	lenticular fining-up sequences, cross & parallel lamination

Fig. 5 Details of the sedimentary facies of the Llandovery Series and adjacent formations in the Llandovery type area. The facies ornaments to the left are those used in Fig. 4.

the Rhydings Formation, correlating with a more widely recognized marine regression at this time (Ziegler 1965, Woollands 1970).

The *Derwyddon Formation* is restricted to the Pen-y-waun fault belt in the east of the area (Figs 3, 4) and is the lateral equivalent of the Rhydings and Wormwood Formations further west and south. The formation is dominated by well-bedded sandstones, coarser and better sorted than in the Rhydings and Wormwood Formations. Parallel lamination is common and large-scale cross-stratification is present. Beds conspicuously rich in *Pentamerus* valves are common. The Derwyddon rests with angular unconformity on the eroded edges of the Crychan, Bronydd, Scrach and Tridwr Formations and is particularly coarse immediately above this contact. The formation records higher energy conditions than elsewhere in the Llandovery area at this time. This probably reflects shallower marine conditions along the recently submerged Pen-y-waun zone. This positive zone may have extended south-westward and joined the extreme south-west of the Llandovery outcrop (transect a). Here also a coarse lateral equivalent (unnamed) of the Rhydings/Wormwood Formations overlies a marked unconformity.

The *Cerig Formation* comprises silty mudstones similar to some lithologies in the Rhydings Formation but less well-cemented and resistant. The mudstones are commonly parallel-laminated and occasionally bioturbated, with sporadic large-scale slumped zones. The upper part of the Formation in the central area (e.g. transect d) has numerous thin intercalations of fine cross-laminated sandstones. The Cerig Formation blankets the whole of the underlying Llandovery sequence, even in the shallow south-eastern areas. It probably records a further transgressive pulse, resulting in open marine shelf deposition over the whole area. The cross-laminated sandstone facies in the central area suggest shallowing there late in Llandovery time.

The *Gwernfelen Formation* comprises uniformly finely laminated muddy siltstones of Wenlock age (e.g. transect d). Over most of the area these rocks overlie the Cerig Formation conformably. In the Pen-y-waun fault belt contacts of Wenlock rocks with lower horizons are probably faulted, as is the Wenlock/Ordovician contact to the north-east. The origin of the Gwernfelen facies is problematical. It is common elsewhere in the British Wenlock and similar sediments have been interpreted as distal turbidites in a deep basin (Piper 1972). This seems an unlikely interpretation in this area. Constant weak traction currents ('contour currents') flowing across a deepened marine shelf are another possibility.

Structure

The Llandovery Series rocks have been affected by only one important episode of deformation, probably culminating in latest Silurian to mid-Devonian time. The resulting structure is relatively simple and is directly visible on the geological map (Figs 2 and 3).

At the north-eastern end of the area a major syncline/anticline pair plunges gently south-west. The folds have a wavelength of about 3·5 km. They are asymmetric to the south-east, with steep limbs younging south-east flanking a gently dipping limb younging north-west. A weak axial-planar cleavage dips steeply north-west, but is often absent in the gentle limb. The steep limbs are cut by sub-vertical faults striking north-east to south-west, mostly downthrowing to the south-east. The south-eastern steep limb, named the Pen-y-waun fault belt, coincides with an unconformity below the later Llandovery rocks (Figs 4 and 68).

Another syncline-anticline pair is seen at the south-western end of the area. This pair has wavelength of about 3 km, is again asymmetric to the south-east, but here plunges gently north-east. A steep fault striking north-east to south-west cuts the anticline hinge and downthrows to the south-east. The south-eastern steep limb is again a zone of sub-Upper Llandovery unconformity (Figs 3, 4), suggesting that it may connect structurally, through steep intervening Wenlock and Ludlow rocks, with the Pen-y-waun fault belt further north-east.

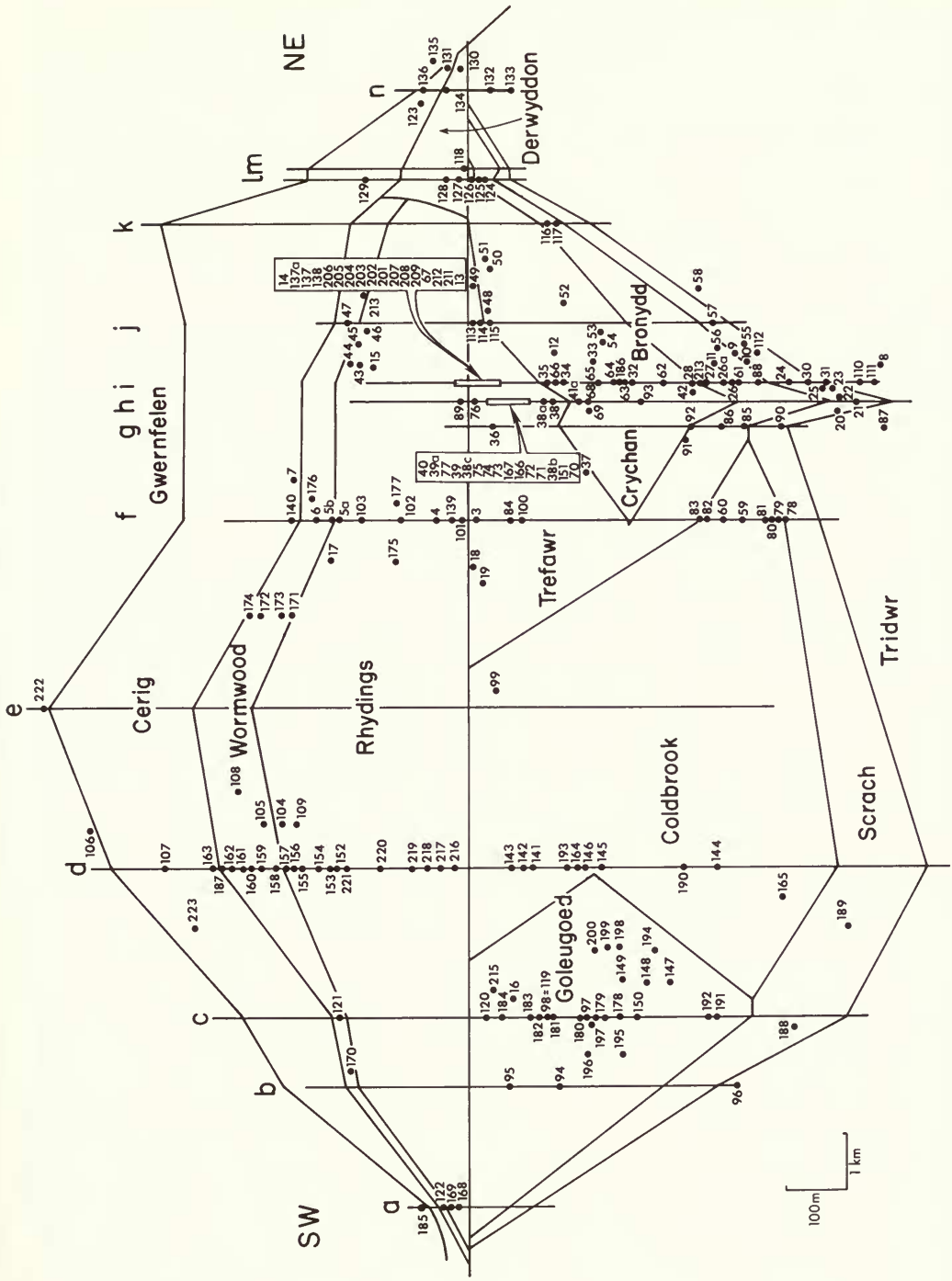


Fig. 6 Fossil locality numbers projected onto a SW–NE section through the Llandovery area. Transects a to n are located on Figs 2 and 3, and gaps and offsets in the transects are shown on Fig. 4, for example the various subsections of transect i. Grid references of the localities are given in Appendix 2, p. 177, and of the ends of the measured parts of the transects in Appendix 3, p. 178.

The central part of the Llandovery area shows no major folding, just a steeply-dipping sequence younging continuously to the south-east.

About half the stratigraphic logs come from gently dipping sequences where the weakness or absence of cleavage suggests only minor tectonic modification of the original compacted thickness. The measured thicknesses in logs taken in steeply-dipping sequences should be more cautiously interpreted. However, even here, much of the folding was accomplished by slip on bedding planes (rather than internal strain of layers) and stratigraphic thicknesses are probably essentially unchanged.

Biostratigraphy

The chief fossil groups from the Llandovery type area are treated individually below, but the faunas from the beds immediately below and above the rocks of Llandovery age in the area need brief discussion here.

It has been known from the time of Jones (1925) that mid-Ashgill faunas are to be found in what we term the Tridwr Formation. These include such forms as *Sampo ruralis* (Reed), *Christiania tenuicincta* (M'Coy), *Chonetoidea papillosa* Jones and *Orthograptus truncatus* (Lapworth), and many more which together indicate a Rawtheyan age for the formation. However, previously unreported are faunas which we have found in the succeeding Scrach Formation (e.g. from Locality 90); this is the formation which includes the restricted and lensing A_1 Sandstone of Jones in the southern part of the area. These faunas include *Eostropheodonta hirnantensis* (M'Coy), *Hirnantia sagittifera* (M'Coy), *Plectothyrella crassicostis* (Dalman), *Dalmanella testudinaria* (Dalman) and an undetermined bryozoan, and can be identified as typical *Hirnantia* faunas of latest Ordovician, Hirnantian age. This is of immense stratigraphical importance, lying as it does under the Bronydd Formation which has a *persculptus* or *acuminatus* Zone graptolite fauna near its base. Other localities in the Scrach Formation have yielded fragments of cyclopygid trilobites, which strengthen the case for a pre-Silurian age.

Above the type Llandovery rocks, the lower Wenlock mudstones and siltstones, termed here the Gwernfelen Formation, have yielded a variety of forms, in particular the graptolite *Monoclimacis vomerina basilica* (Lapworth) from Loc. 185, indicating a basal Wenlock *centrifugus* Zone age. The formation also includes local shelly faunas including forms such as *Leangella, Skenidioides, Clorinda, Encrinurus* and others.

(a) Graptolites

Figs 7 and 19 illustrate the considerable extent to which the Llandovery strata have a graptolite biostratigraphical framework, far greater, in fact, than had hitherto been supposed. The earliest graptolites we have obtained show that the age of the Tridwr Formation is uppermost Ordovician, with an association of *Orthograptus amplexicaulis* (Hall), *Climacograptus angustus* (Perner), ?*C. supernus* Elles & Wood, *Dendrograptus* sp., *Chaunograptus* sp. and ?*Mastigograptus* sp. A horizon very low in the Bronydd Formation (Loc. 88) has yielded a single well-preserved specimen of *Climacograptus normalis* Lapworth, the dimensions and shape of the proximal end and complete median septum of which suggest a horizon certainly no higher than the *acuminatus* Zone, and probably as low as the *persculptus* Zone.

Dating of the bulk of the Bronydd Formation is not easy on direct evidence, although graptolites have been obtained from several localities. But the fact that it is overlain to the north-east by the Crychan Formation, which is largely referable to the *cyphus* Zone (see below), seems to indicate that the Bronydd fauna of *C.* cf. *normalis, Climacograptus rectangularis* M'Coy, *C. angustus, Rhaphidograptus toernquisti* (Elles & Wood) and *Glyptograptus* sp. corresponds approximately to the *atavus* and *acinaces* Zones. There are no direct indicators of the *cyphus* Zone as there are in the overlying beds. Correlation of the lower part of transect f with the lower part of transects g, h and i is feasible, despite the lithological change south-westwards to the Coldbrook Formation, because Loc. 81 yields

TRANSECTS & LOCALITY NUMBERS														graptolites, rhabdopleurans and chitinous hydroids
a	b	c	d	e	f	g	h	i	j	k	l	m	n	
								13						Orthograptus amplexicaulis (Holl)
													133	Climacograptus supernus E. & W.
													133	Mostigograptus sp.
							70	31						Dendrograptus sp. / Dictyonemo sp.
					81			31						Climacograptus angustus E. & W.
					37			88,26						Climacograptus normalis Lopw.
					59			14						Glyptograptus sp.
			141,		81									P.(Metoclimacograptus) fidus/pictus K&M.
			164		5,81,101 S		N	N						Rhophidograptus taernquisti E. & W.
			142		18			26,35						Climacograptus rectonguloris M'Coy
					37									Pribylograptus incommodus Törnq.
								35						P.(Metaclimacograptus) hughesi (Nich.)
								35						Atavograptus strochoni Hutt & Rick.
			157					14,35					131	Monograptus sp.
			145,				70	31						Climacograptus sp.
			141,				70							Logorograptus ocinoces (Törnq.)
							70							Monogr. ousterus vulgoris Hutt
							70							Dictyonemo corrugotellum Lopw.
							151							Diplograptus elongotus Churkin & C.
							151							Pseudoglyptograptus sp. I. Rick. 1972
					100									Monograptus revolutus Kurck
					100									Monogr. triangulotus seporatus Sud.
			142		100									Manogr. triangulotus fimbriotus Nich.
			146											Climacograptus olternis Pockhom
			145		101		S							P.(Clinoclimacograptus) retroversus B.&R.
							72							Manogr. austerus sequens Hutt
			141,				166,S							G.(Pseudoglyptograptus) vas B. & R.
			146				166							G. tomariscus lineoris (Perner)
							73							Rastrites peregrinus Borr.
							166							Orthogr. insectiformis Nich.
			143											Glyptogr. incertus E. & W.
			142,		100		73							Diplogr. magnus H. Lapw.
			146,											Petalogr. minor Elles
			143											G. t. tamariscus Nich.
			142											Orthogr. cyperoides Törnq.
			143											indeterminote biseriols
	94				84	38	75							Dictyonema venustus Lopw.
							75							Discograptus sp.
							38c							Atavograptus otovus (Jones)
							38c							Karemograptus sp.
								67						Pristiograptus reguloris (Törnq.)
							39o							Orthograptus sp.
						36								Monogr. convolutus (Hisinger)
					101									Orthogr. bellulus
								14						Rastrites linnoei
								14						Monograptus sedgwickii (Portl.)
							89			& Sefin River				Logaragroptus tenuis (Portl.)
														Monogr. runcinotus Lopw.
													131	Rhobdopleuro sp. nov.
													131	chitinous hydroids
													133	P. (Metoclimocograptus) sp.
					140	36								

Fig. 7 Graptolite records tied to locality numbers and the transects shown in Figs 2–4. The symbol N indicates numerous localities on this transect and S indicates several localities.

Pseudoclimacograptus (*Metaclimacograptus*) cf. *fidus* Koren' & Mikhailova or, possibly, *P.* (*M.*) *pictus* Koren' & Mikhailova, both of which occur in the *acuminatus* Zone of the U.S.S.R. Thus a horizon quite low in the Coldbrook Formation is probably referable to the *acuminatus* Zone. The Bronydd Formtion probably ranges in age from the *persculptus* or *acuminatus* Zone near its base to the *acinaces* or low *cyphus* Zone at its top.

The Crychan Formation has yielded *Pseudoclimacograptus* (*Metaclimacograptus*) cf. *hughesi* (Nicholson) and *Glyptograptus* ex gr. *tamariscus* (Nicholson) in the middle, and *P.* (*M.*) *hughesi, Climacograptus* sp., *C.* ?*rectangularis*, cf. *R. toernquisti, Atavograptus* ?*strachani* (Hutt & Rickards) and *Monograptus* sp. towards the top, suggesting that the bulk of the formation is referable to the *cyphus* Zone although the lower part could be in part *acinaces* Zone. A locality at the very top of the Crychan Formation (Loc. 35, transect i) has yielded *A.* ?*strachani* and possibly triangulate monograptid thecae. The latter thecal type first appears in the upper part of the *cyphus* Zone and becomes more typical of higher levels.

Graptolites are most common in the Trefawr Formation and equivalents, occurring in abundance at numerous localities, and they allow recognition of the *cyphus, triangulatus, magnus* and *convolutus* Zones with good lower boundaries for the first two of these zones. The base of the *triangulatus* Zone can be taken at the base of Loc. 72 (transect h) within the Trefawr Formation. Above this level occurs *Monograptus austerus sequens* Hutt (Loc. 72), a *triangulatus* Zone form; below this level *Monograptus* cf. *austerus vulgaris* Hutt, *Diplograptus elongatus* Churkin & Carter, ?*Pseudoglyptograptus* sp. 1 (*sensu* Rickards 1972) and cf. *Lagarograptus acinaces* Törnquist (or ?*C. cyphus*) indicate the *cyphus* Zone.

Loc. 100, on transect f, is at the same stratigraphical level as Loc. 72, and yields *Monograptus* cf. *revolutus* Kurck *s.s., Monograptus triangulatus* ?*separatus* Sudbury, *M. t.* ?*fimbriatus* (Nicholson), *R. toernquisti* and *Diplograptus* cf. *magnus* Lapworth, which also indicate a *triangulatus* Zone attribution.

The best sequence through the *triangulatus* Zone into the *magnus* Zone is in transect h, where the base of the *magnus* Zone is marked by the incoming of *Glyptograptus* (*Pseudoglyptograptus*) *vas* Bulman & Rickards (Fig. 13), *Orthograptus insectiformis* (Nicholson) and *Glyptograptus tamariscus* cf. *linearis* (Perner) at the base of Loc. 166. Various *D. magnus*-like forms occur immediately above this and continue to be associated with *G.* (*P.*) *vas*.

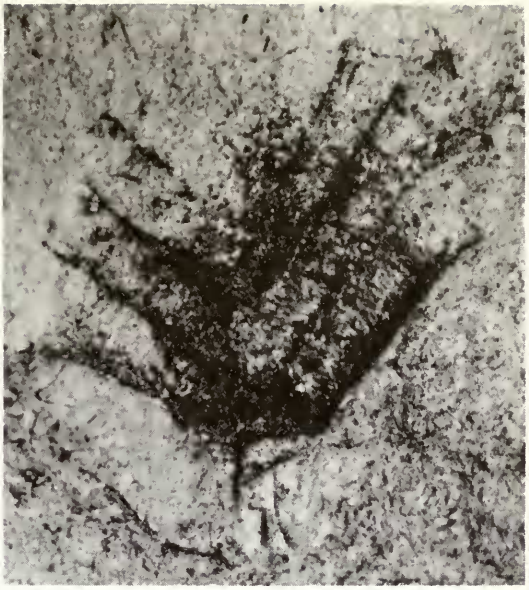
The *magnus* Zone fauna is well represented at numerous other localities and is typified by the eponymous taxon and by *Glyptograptus* (*Pseudoglyptograptus*) *vas* Bulman & Rickards and *Orthograptus insectiformis* Nicholson. Numbers of other species occur which are in accord with the attribution of strata above the base of Loc. 166 (transect h) to the *magnus* Zone (Figs 7, 19). A good *magnus* Zone assemblage also occurs on the Cefn Cerig Road section (transect d), where it is also underlain by strata possibly referable to the *triangulatus* Zone which contain *Climacograptus* ?*alternis* Packham.

Most of the Trefawr Formation on the transect h section above Loc. 166 yields a *magnus* Zone fauna, but Loc. 36, stratigraphically just below the *sedgwickii* Zone of the Rhydings Formation, yields a *convolutus* Zone fauna: Jones (1949) recorded *Monograptus decipiens* Törnquist, *M.* cf. *lobiferus* M'Coy, *Pristiograptus regularis* (Törnquist) and *Orthograptus cyperoides* Törnquist, while we have found *Orthograptus* sp., *R. toernquisti* and ?*Pseudoclimacograptus* sp. On the main Trefawr track nearby (transect h) the change to *convolutus* probably takes place at about Loc. 39, the highest probable *magnus* level being at Loc. 74. Between Locs 74 and 39 there are at least 30m of strata, so far yielding only undiagnostic, yet not infrequent, graptolites.

The *sedgwickii* Zone is indicated at two localities, both near the base of the Rhydings Formation. Loc. 89 (transect h) yields *M.* cf. *sedgwickii* Portlock, and the collection from Loc. 14 (transect i) contains *Orthograptus* cf. *bellulus* Törnquist, *Rastrites* aff. *linnaei* Barrande, *Glyptograptus* sp. and *Monograptus* sp. *s.s.* Loc. 101 (transect f) yields *M.* aff. *convolutus* (Hisinger), so that it is probable that the base of the *sedgwickii* Zone is only a few metres above the base of the Rhydings Formation. The Sefin River also yields *M. sedgwickii* and *Lagarograptus tenuis* (Portlock) at the same level.

8

9



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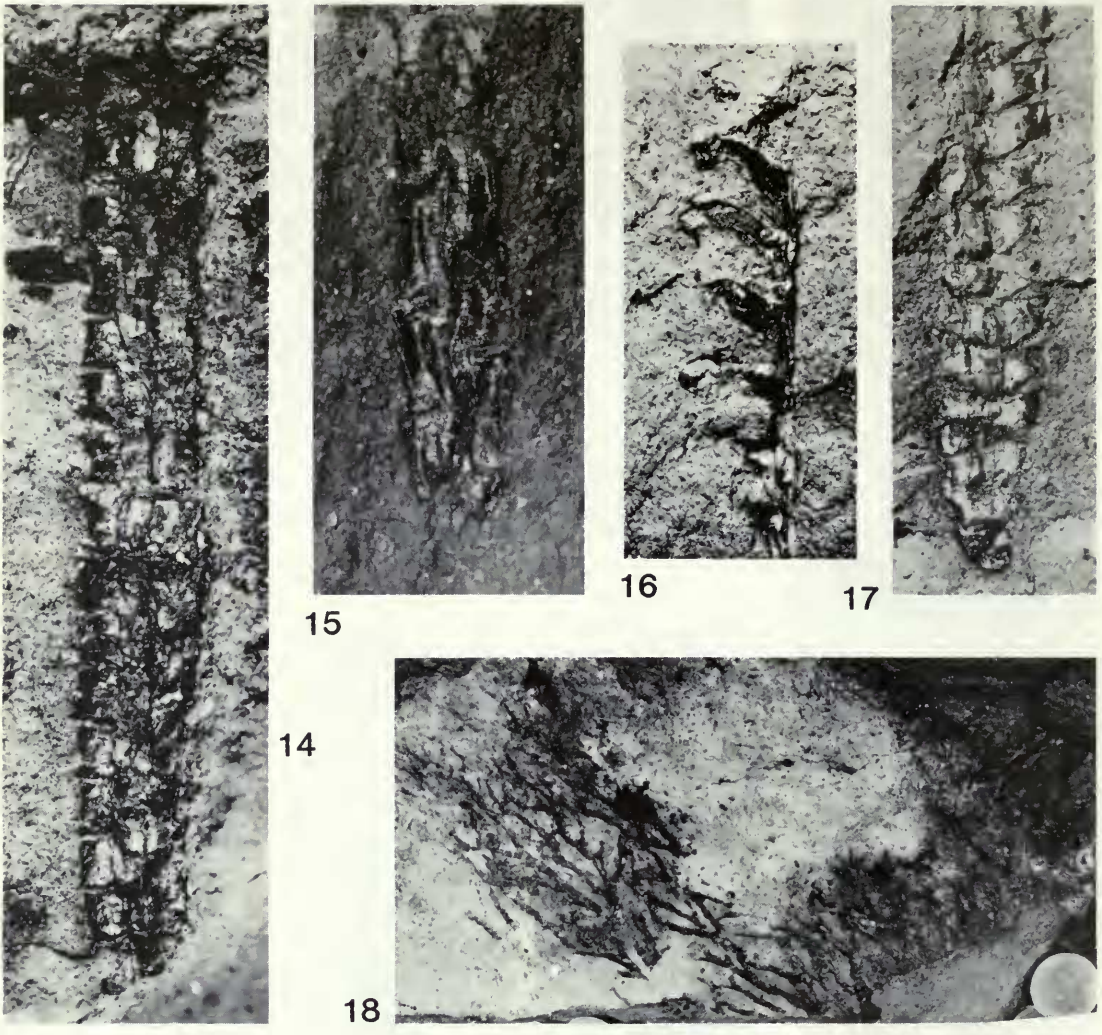
13

Figs 8–13 Graptolites from the type Llandovery area (SM = Sedgwick Museum, Cambridge). Fig. 8, *Diplograptus* cf. *magnus* H. Lapworth, 1900, proximal region in partial relief, somewhat distorted; SM A109544, ×20; *triangulatus* Zone, Trefawr Formation, Loc. 100. Fig. 9, *Rhaphidograptus toernquisti* (Elles & Wood, 1906), obverse view of proximal end in low relief, showing sicula and virgella; SM A105946, ×15; *cyphus* Zone, Trefawr Formation, Loc. 38. Fig. 10, *Petalograptus minor* Elles, 1897, proximal end with virgella; SM X330, ×20; *magnus* Zone, Coldbrook Formation, Loc. 143. Fig. 11, *Climacograptus ?alternis* Packham, 1962, reverse view of proximal end in three dimensions; SM X329, ×20; *triangulatus* Zone, Coldbrook Formation, Loc. 146. Figs 12, 13, *Glyptograptus* (*Pseudoglyptograptus*) *vas* Bulman & Rickards, 1968; Fig. 12, proximal end in low relief; SM X331, ×10; *magnus* Zone, Trefawr Formation, Loc. 166; Fig. 13, proximal region in low relief; SM A105938, ×20; *magnus* Zone, Coldbrook Formation, Loc. 142.



Figs 14–18 Graptolites from the type Llandovery area, cont. Fig. 14, *Rhaphidograptus toernquisti* (Elles & Wood, 1906), distal thecae in low relief; SM X332, ×10; *cyphus* Zone, Trefawr Formation, Loc. 38. Fig. 15, *Pseudoclimacograptus* (*Clinoclimacograptus*) *retroversus* Bulman & Rickards, 1968, proximal end in moderate relief; SM A105951, ×20; *triangulatus* Zone, Coldbrook Formation, Loc. 81. Fig. 16, *Monograptus triangulatus* cf. *fimbriatus* (Nicholson, 1868), early mesial thecae in low relief; SM A105723, ×10; *magnus* Zone, Coldbrook Formation, Loc. 142. Fig. 17, *Glyptograptus* (*Pseudoglyptograptus*) ?sp. 1 *sensu* Rickards (1972), proximal and mesial regions in low relief; SM X334, ×10; *cyphus* Zone, Trefawr Formation, Loc. 151. Fig. 18, *Koremagraptus* sp., fragmentary part of large rhabdosome; SM A105954, ×3; *magnus* Zone, Trefawr Formation, Loc. 67.

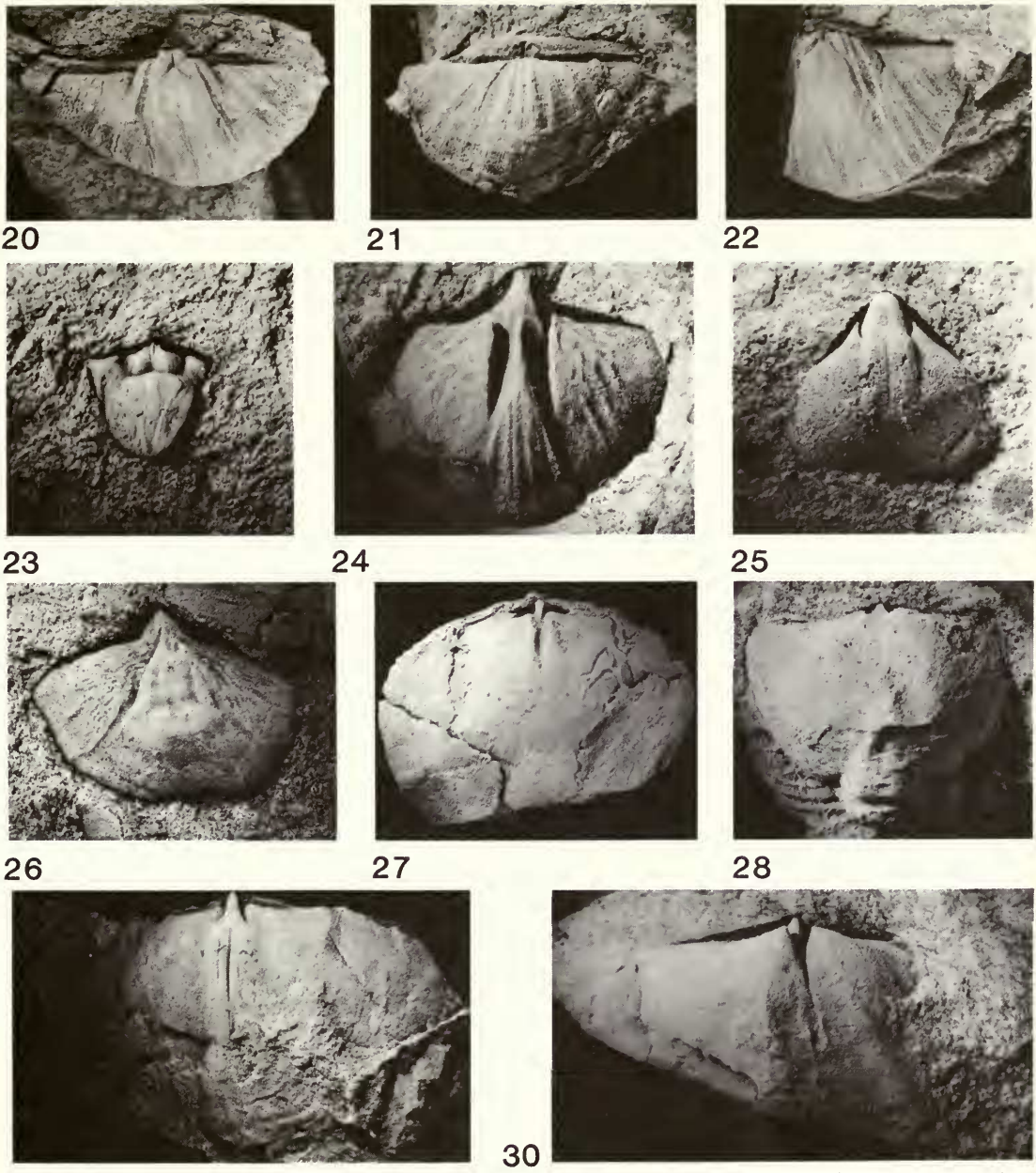
Above the Rhydings Formation, graptolites have proved to be rare. But *Monograptus runcinatus* Tullberg occurs near the base of the Cerig Formation (Loc. 131, transect n) and ?*Pseudoclimacograptus* (*Metaclimacograptus*) sp. at Loc. 140, transect f; thus we would place the base of the Cerig Formation near the base of the *turriculatus* Zone.

Graptolite Zones / graptolites rhabdopleurans & chitinous hydroids	supernus	"persculptus"	acuminatus	"atavus"	"acinaces"	cyphus	triangulatus	magnus	"argenteus"	convolutus	sedgwickii	turriculatus
Orthograptus amplexicaulis (Hall)	●											
Climacagraptus supernus E. & W.	?											
Mastigagraptus sp.	?											
Dendrograptus sp. / Dictyonema sp.	●					●						
Climacagraptus angustus E. & W.	●		●									
Climacograptus normalis Lapw.		●		cf.		aff.						
Glyptagraptus sp.				●							●	
P.(Metaclimacagraptus) fidus/pictus K&M.			●									
Rhaphidagraptus toernquisti E. & W.			cf.	●	●	●	●	●	●	●	●	
Climacagraptus rectangularis M'Coy				●	?			?		cf.		
Pribylagraptus incommodus Törnq.						●						
P.(Metaclimacograptus) hughesi (Nich.)					cf.	cf.						
Atavograptus strachani Hutt & Rick.						?						
Monagraptus sp.						●					●	●
Climacagraptus sp.	●					●	●	●				
Lagaragraptus acinaces (Törnq.)						cf.						
Monagr. austerus vulgaris Hutt						●						
Dictyonema carrugatellum Lapw.						?						
Diplagraptus elangatus Churkin & C						aff.						
Pseudaglyptagraptus sp. I. Rick. 1972						?						
Monagraptus revolutus Kurck							cf.					
Monagr. triangulatus separatus Sud							?					
Monagr. triangulatus fimbriatus Nich.							?	cf.				
Climacagraptus alternis Packham							?					
P.(Clinoclimacograptus) retroversus B.&R.							●	●	●	●	?	
Monogr. austerus sequens Hutt							●					
G.(Pseudoglyptagraptus) vas B. & R.							?	●				
G. tamariscus linearis (Perner)								cf.				
Rastrites peregrinus Barr.								●				
Orthogr. insectiformis Nich.								●				
Glyptagr. incertus E. & W.								?				
Diplogr. magnus H. Lapw.							?	●				
Petalogr. minor Elles								●				
G. t. tamariscus Nich.								●				
Orthagr. cyperoides Törnq.								cf.				
indeterminate biserials						●		●		●		
Dictyonema venustus Lapw.										●		
Discograptus sp.										●		
Atavagraptus atavus (Janes)								?				
Karemagraptus sp.								●				
Pristiagraptus regularis (Törnq.)										cf.		
Orthagraptus sp.										●		
Monagr. convalutus (Hisinger)											aff.	
Orthogr. bellulus											cf.	
Rastrites linnaei											aff.	
Monograptus sedgwickii (Portl.)											●	
Lagaragraptus tenuis (Portl.)												
Monagr. runcinatus Lapw.												●
Rhabdopleura sp. nav.												●
chitinous hydraids	●											
P. (Metaclimacograptus) sp.										●		●

Fig. 19 Graptolites found and zones recorded from the type Llandovery area. Each species is recorded at its highest taxonomic level (i.e. 'aff.' rather than '?') when several localities are involved. The text is strictly accurate in its attributions. Graptolite zones in quotation marks indicate that the zonal indicators have not been found, but that other graptolites are present at that approximate level. The black dots indicate specimens found in the appropriate zones in the type Llandovery area.

Table 1 Early Llandovery brachiopods and other faunas from localities in the Scrach section (transect i) in the northern Llandovery area. Counting conventions for this and Tables 2 to 5 are: brachiopods – umbonal fragments only counted; ostracods and bivalves – number of valves; trilobites – numbers of cranidia + pygidia; other groups – numbers of specimens; '×' denotes occurrence of items such as crinoid ossicles where the number of original animals represented is difficult to determine.

Formations	Bronydd				Crychan										
Localities	61a	26	26a	27	224	28c	32	63	186	64	65	34	34a	66	35
Sample mass (kg)	1·9	11·4	5·9	6·8	16·6	3·6	4·2	3·6	4·3	15·7	6·1	11·0	5·7	4·2	2·2
Brachiopods															
Inarticulata indet.	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dolerorthis sowerbyiana	–	1	2	–	–	–	1	–	–	2	–	–	–	–	2
Schizonema sp.	–	–	1	5	–	–	–	–	–	–	–	–	–	–	–
Giraldiella sp.	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Skenidioides sp.	1	1	18	–	–	–	–	–	–	4	1	–	–	–	1
indet. orthaceans	–	–	7	11	–	–	–	–	–	1	–	–	–	–	1
Ravozetina sp.	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–
'Resserella' sp.	–	3	41	26	–	1	4	1	4	18	10	–	–	–	6
Dicoelosia sp.	–	–	–	1	–	–	–	–	–	1	–	–	–	–	–
Visbyella sp.	–	–	–	–	–	–	–	–	–	–	–	20	–	–	1
indet. enteletaceans	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–
Triplesia sp.	1	2	–	–	–	–	–	–	–	1	1	–	–	–	–
Leangella scissa	–	1	29	26	1	–	1	1	3	9	4	–	–	1	3
Anisopleurella sp.	1	5	1	–	–	–	1	–	–	1	–	–	–	–	–
Eoplectodonta duplicata	10	13	28	20	–	1	3	2	2	12	1	–	3	2	8
Katastrophomena sp.	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Leptaena valentia	–	1	3	1	–	–	–	–	1	–	2	–	–	–	1
'Leptaena' reedi	–	–	1	2	–	–	–	–	–	4	–	–	–	–	–
Eopholidostrophia sp.	–	–	1	–	–	–	–	–	–	1	–	–	–	–	–
Leptostrophia sp.	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–
Fardenia sp.	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–
indet. strophomenides	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Stricklandia lens	–	–	–	–	19	4	1	–	–	1	1	53	25	38	–
Clorinda undata	–	–	–	17	–	–	–	–	–	–	2	–	–	–	–
indet. pentamerids	15	1	–	–	–	–	–	–	–	–	–	2	–	–	–
Rhynchotrema sp.	–	1	1	–	1	–	–	1	–	1	–	–	–	–	–
Protozyga sp.	–	–	4	–	–	–	–	–	–	–	–	–	–	–	–
Plectatrypa sp.	5	3	16	4	–	4	–	–	–	–	1	–	–	–	–
Meifodia sp.	–	–	–	69	17	14	–	–	–	–	1	–	8	–	–
Cryptothyrella angustifrons	33	16	246	41	6	1	–	–	–	–	–	–	–	–	–
Cryptothyrella crassa	–	–	–	14	–	2	–	–	–	1	–	1	–	–	–
indet. spiriferides	1	–	1	8	–	1	–	–	–	–	–	–	–	–	–
indet. articulates	1	1	1	3	1	–	–	–	–	1	1	2	–	–	–
Total brachiopods	69	50	405	251	45	28	11	5	10	60	25	78	36	42	23
Other phyla															
solitary coral	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
compound coral	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
Leonaspis sp.	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
other trilobites	–	×	–	–	–	–	–	–	–	–	–	–	–	–	×
graptoloids	–	–	–	–	–	–	–	–	–	1	1	–	–	4	4
gastropods	–	–	22	2	–	–	–	–	–	2	–	1	–	–	1
bivalve	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
crinoid columnals &c.	×	×	×	–	–	–	–	–	–	–	–	–	–	–	×
echinoderm plates	–	–	–	–	–	–	1	–	–	1	–	–	–	–	–
bryozoans	×	–	–	×	–	–	–	–	×	×	–	–	–	–	–
Incertae sedis	–	2	–	–	–	–	–	–	2	–	2	–	–	–	2



Figs 20–30 Brachiopods from the Rhuddanian Stage (BB, British Museum (Natural History) specimens). Figs 20–22, *Eoplectodonta duplicata* (J. de C. Sowerby, 1839), Goleugoed Formation; Fig. 20, internal mould of pedicle valve, BB 68640, ×2, Loc. 180; Fig. 21, external mould of brachial valve, BB 68641, ×2·5, Loc. 214; Fig. 22, internal mould of pedicle valve, GSM Geol. Soc. Coll. 6874, lectotype, ×2, locality 'Cefn Rhyddan'. Fig. 23, *Leangella scissa* (Davidson, 1871), internal mould of pedicle valve; BB 68647, ×2; Goleugoed Formation, Loc. 180. Fig. 24, *Cryptothyrella crassa* (J. de C. Sowerby, 1839), internal mould of pedicle valve, GSM Geol. Soc. Coll. 6901, lectotype, ×2, Goleugoed Formation, locality 'Cefn Rhyddan'. Fig. 25, *Cryptothyrella angustifrons* (Salter, 1851), internal mould of pedicle valve; BB 68644, ×4; Bronydd Formation, Loc. 26A. Figs 26–28, *Meifodia subundata* (M'Coy, 1851), Bronydd Formation, Loc. 27; Fig. 26, internal mould of pedicle valve, BB 68648, ×2; Figs 27, 28, internal moulds of brachial valves, BB 68646 and BB 68645, both ×2. Figs 29–30, *Stricklandia lens* (J. de C. Sowerby, 1839), Loc. 97A; Fig. 29, internal mould of brachial valve, BB 68643, ×2; Fig. 30, internal mould of pedicle valve, BB 68642, ×2.

Table 2 Early Llandovery brachiopods and other faunas from localities in the Trefawr section (transect h), which includes the basal stratotype of the Aeronian Stage in the northern Llandovery area.

Formations	Crychan	Trefawr														
Localities	41a	38s	38a	70	70a	38b	71	72	73	74	75	38c1	38c	39	39a	76
Sample mass (kg)	4·5	2·2	2·0	4·2	4·0	2·3	4·4	4·5	5·5	7·1	3·5	–	11·7	2·4	2·5	3·6
Brachiopods																
discinids	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
craniids	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–
indet. inarticulates	–	2	1	–	–	–	–	–	–	–	–	–	–	–	–	–
Dolerorthis sowerbyiana	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
Dolerorthis sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
Skenidioides sp.	1	–	–	7	6	–	1	4	1	7	3	–	4	–	–	–
'Resserella' sp.	2	–	1	10	4	1	–	–	–	2	3	–	9	–	–	3
Dicoelosia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
Triplesia sp.	–	–	–	–	–	–	1	2	–	–	1	1	–	–	5	1
Streptis sp.	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
Leangella scissa	2	–	–	–	10	5	1	–	3	5	7	–	5	–	–	1
Anisopleurella sp.	–	–	–	–	5	5	–	1	6	1	–	–	7	–	–	–
Eoplectodonta duplicata	2	4	–	–	7	3	–	–	–	4	1	–	7	2	–	–
Aegiria sp.	–	–	6	–	–	–	–	–	2	4	–	–	–	–	–	–
Katastrophomena sp.	1	1	–	–	–	–	–	–	–	–	–	1	–	–	–	–
Leptaena valentia	–	–	–	–	–	–	–	–	1	–	–	–	3	1	–	–
'Leptaena' reedi	–	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–
Pentlandina sp.	–	–	–	–	1	–	–	–	6	6	–	–	–	–	–	–
Eopholidostrophia sp.	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
indet. strophomenides	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Stricklandia lens	22	–	–	–	1	–	1	–	–	3	2	3	–	–	1	3
Clorinda undata	–	–	–	–	–	1	7	8	1	–	1	–	14	6	9	17
Rhynchotrema sp.	–	–	–	–	2	–	–	1	–	–	–	–	20	7	–	–
Plectatrypa sp.	–	10	–	–	2	–	5	3	–	–	–	–	8	9	–	22
Meifodia sp.	–	–	1	–	–	–	–	1	13	20	2	6	16	10	37	15
Cryptothyrella crassa	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–
indet. spiriferides	1	–	2	–	2	–	–	–	7	8	2	–	–	–	2	1
indet. articulates	3	–	–	2	–	1	3	1	1	–	1	–	–	–	–	–
Total brachiopods	35	18	11	20	42	17	19	21	42	60	23	11	95	36	55	66
Other phyla																
solitary corals	–	–	–	–	1	–	–	1	–	–	–	–	1	–	–	–
illaenid trilobites	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
calymenid trilobites	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–
other trilobites	–	–	–	–	×	×	–	×	–	–	–	–	–	–	–	–
ostracods	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–
graptoloids	–	2	–	2	2	–	–	–	8	–	11	–	3	–	–	–
dendroid	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
gastropods	–	–	–	2	–	–	–	1	1	1	–	–	–	–	–	–
cephalopod	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–
crinoid columnals &c.	–	–	–	–	–	×	–	–	–	×	×	–	×	–	–	–
echinoderm plates	–	2	2	–	–	–	1	–	1	1	–	–	–	–	–	–
bryozoans	×	–	–	–	–	×	–	×	–	–	–	–	×	–	–	×
Incertae sedis	–	–	–	–	–	1	–	2	–	–	–	–	1	–	–	–

Table 3 Early Llandovery brachiopods and other faunas from localities in the Cwm-coed-aeron section (transect i) in the northern Llandovery area.

Formations	Trefawr													Rhydings	
Localities	211	212a	212	67	209	208	207	201	202	203	204	205	206	138	137a
Sample mass (kg)	4·5	2·0	4·6	8·7	4·6	8·6	2·2	5·0	5·0	4·7	9·9	7·5	5·2	8·1	8·5
Brachiopods															
lingulacean	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–
Paracraniops sp.	–	–	–	–	–	–	–	–	–	–	6	–	–	–	–
Dolerorthis sowerbyiana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Schizonema sp.	–	–	–	–	–	–	–	–	–	–	4	–	–	–	–
Giraldiella sp.	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–
indet. orthaceans	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–
Ravozetina sp.	–	–	–	–	–	–	–	–	–	–	–	3	–	–	–
'Resserella' sp.	–	–	–	–	–	–	–	–	–	–	9	2	–	1	1
Dicoelosia sp.	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–
Triplesia sp.	–	–	–	–	–	–	–	–	–	–	1	–	–	–	4
Eoplectodonta sp.	–	–	–	–	–	1	–	–	–	–	9	14	–	–	2
Katastrophomena sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	1	2
Leptaena valentia	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Stricklandia lens	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
Clorinda undata	–	–	1	4	–	–	1	–	–	1	9	62	–	–	–
Pentamerus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
Rhynchotrema sp.	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
Plectatrypa sp.	1	–	–	–	4	8	–	4	–	–	1	6	–	–	1
Meifodia sp.	6	4	–	5	3	14	1	7	2	1	21	36	10	3	1
indet. spiriferides	7	–	1	3	–	–	–	–	–	–	–	2	–	–	1
indet. articulates	–	–	–	1	–	–	–	–	–	–	3	2	–	–	–
Total brachiopods	14	4	2	17	7	23	2	13	3	2	66	127	10	6	13
Other phyla															
echinoderm plates	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–
bryozoans	–	–	–	–	–	–	–	–	–	–	×	×	–	–	–
Incertae sedis	–	–	1	–	–	–	–	1	–	–	1	–	–	–	–

(b) Brachiopods from the lower part of the series (pre-Rhydings Formation)

Brachiopods form the dominant elements of the shelly faunas in both the northern and southern areas. In the northern area a total of 1978 brachiopods have been collected from 47 sites (mean sample size 42·1), and in the southern area 1277 brachiopods from 12 sites (mean sample size 106·4). The difference in numbers of sites reflects the more continuous exposures in the north, which lend themselves to closely-spaced sampling.

Plots of number of recorded species against size of sample reveal no evidence of differences in overall diversity of brachiopod faunas between the northern and southern areas. There are, however, more taxa which have been found only in the north (10) than only in the south (2), and although most of these are rare forms whose absence can probably be attributed to defects of sampling, there are four taxa whose absence from the south may be more significant – *Aegiria, Cryptothyrella angustifrons, Pentlandina* and *'Leptaena' reedi*. The first three of these are found in the Garth area a few km to the north of the northern area, while *'Leptaena' reedi* is otherwise unknown in early Llandovery strata anywhere south of the Berwyn outcrop.

The early Llandovery brachiopods do not form well-defined assemblages or 'communities', with the exception of *Stricklandia*-dominated assemblages which occur in the middle parts of the successions in both areas – Locs 97b–183 in the south, and Locs 34–66 (including 41a) in the north. These *Stricklandia*-dominated assemblages show extremely low diversity (and high

Table 4 Early Llandovery brachiopods and other faunas from localities in the Ydw Valley (transect c) in the southern Llandovery area.

Formations	Goleugoed											
Localities	150	178	179	97b	97a	180	98	181	182	183	184	120
Sample mass (kg)	6·0	–	18·7	–	–	19·8	–	3·6	2·3	–	12·6	–
Brachiopods												
lingulacean	–	–	1	–	–	–	–	–	–	–	–	–
Dolerorthis sowerbyiana	–	1	–	–	–	–	–	–	–	–	1	6
Schizonema sp.	–	1	1	2	–	1	–	–	–	–	–	2
Giraldiella sp.	–	1	–	–	–	–	–	–	–	–	–	2
Skenidioides sp.	–	2	1	4	–	10	–	–	–	1	–	2
indet. orthaceans	–	1	–	–	1	1	–	–	–	–	–	–
Ravozetina sp.	–	–	–	–	–	3	–	–	–	–	1	1
'Resserella' sp.	1	11	8	17	8	45	2	2	2	–	2	9
Dicoelosia sp.	–	2	–	–	–	–	–	–	–	–	–	–
Visbyella sp.	–	–	2	–	1	4	–	–	–	–	–	–
Saukrodictya sp.	–	–	–	–	1	–	–	–	–	–	–	–
indet. enteletaceans	–	–	–	–	–	1	–	–	–	–	3	–
Triplesia sp.	–	–	–	–	–	2	–	–	–	–	3	2
Leangella scissa	–	20	5	26	13	62	–	2	3	6	3	20
Anisopleurella sp.	3	–	–	–	–	3	–	–	–	–	–	15
Eoplectodonta duplicata	1	26	3	13	8	66	–	1	3	2	2	26
Katastrophomena sp.	–	3	–	1	–	–	–	–	–	–	–	2
Leptaena valentia	–	2	–	–	–	1	–	–	–	–	–	15
Eopholidostrophia sp.	–	2	–	–	–	–	–	–	–	–	–	2
Leptostrophia sp.	–	–	–	–	–	–	–	–	–	–	–	1
Eostrophonella sp.	–	–	–	–	–	1	–	–	–	–	–	–
Fardenia sp.	–	2	–	1	–	1	–	–	–	–	–	–
Stricklandia lens	1	12	2	79	71	6	–	84	3	108	5	2
Clorinda undata	–	–	–	2	2	2	–	1	–	–	10	24
indet. pentamerides	–	–	–	1	8	–	36	–	–	–	1	4
Rhynchotrema sp.	–	2	–	–	–	3	–	–	–	–	3	7
Plectatrypa sp.	–	2	2	3	–	2	–	1	–	1	10	35
Meifodia sp.	–	5	–	–	1	2	1	1	2	–	19	92
Cryptothyrella crassa	–	21	–	2	–	–	–	–	–	–	–	–
indet. spiriferides	–	–	–	–	–	–	–	–	–	–	–	14
indet. articulates	–	8	3	9	3	7	–	–	1	–	1	8
Total brachiopods	6	124	28	160	117	223	39	92	14	118	64	292
Other phyla												
solitary corals	–	–	1	–	–	3	–	–	–	–	–	1
compound coral	1	–	–	–	–	–	–	–	–	–	–	–
illaenid trilobites	–	2	–	–	–	–	–	–	–	–	–	–
calymenid trilobites	–	–	–	–	–	2	–	–	–	–	–	–
Encrinurus sp.	–	1	–	–	–	–	–	–	–	–	–	–
Leonaspis sp.	–	–	–	–	–	–	–	–	–	1	–	–
other trilobites	×	–	–	–	–	–	–	–	–	–	–	×
graptoloids	–	–	2	–	–	1	–	–	–	–	–	1
gastropods	–	–	2	3	–	–	–	–	–	–	–	–
cephalopod	–	–	–	–	–	1	–	–	–	–	–	–
crinoid columnals &c.	×	–	×	×	–	×	–	–	×	–	–	–
echinoderm plate	–	–	–	–	–	1	–	–	–	–	–	–
bryozoans	×	×	–	×	–	×	–	–	×	×	–	×
Incertae sedis	1	–	–	–	–	1	–	–	–	–	–	–

dominance) compared with assemblages dominated (relatively weakly) by '*Resserella*', *Eoplectodonta* (Figs 20–22) or *Meifodia* (Figs 26–28): contrast, for instance, Loc. 183 with Loc. 178 in the south, and Loc. 34a with Loc. 64 in the north (Tables 1–4).

The sequences of early Llandovery brachiopod faunas in the south and north have been slotted into each other, using the program developed by Gordon (1980). Results of this slotting suggest that the lowest part of the northern section, the Bronydd and lower Crychan Formations (Loc. 61a up to around Loc. 62), is earlier than the lowest abundant sample (Loc. 178) from Ydw Valley, and this part of the northern section is therefore represented by largely unfossiliferous strata in the south. From this horizon upwards, i.e. within the upper part of the Crychan and Trefawr Formations in the north and within the upper part of the Goleugoed Formation in the south, the sequence of early Llandovery brachiopod faunas in the two areas is roughly parallel, although with local reversions and intercalations: '*Resserella*'- and *Eoplectodonta*-dominated assemblages are followed by assemblages (well represented in the south) strongly dominated by *Stricklandia*, and then by *Meifodia*- and *Plectatrypa*-dominated assemblages. These parallel changes in the composition of the brachiopod faunas presumably reflect parallel changes in the environment in the northern and southern areas during the upper part of the early Llandovery. Detailed systematic work on the early Llandovery brachiopod faunas is still proceeding. The taxa listed on Tables 1–4 are mostly interpreted in the sense of Temple (1970).

(c) Brachiopods from the upper part of the series (Rhydings Formation upwards)

Brachiopods can be found at most upper Llandovery outcrops in all parts of the area and some representative collections are shown in Table 5. These collections, from the southern part of the area, are larger than those (unlisted here) from the north of the Llandovery area, and reflect a genuinely greater abundance and diversity in the south: the reverse of the situation in the Lower Llandovery. The most important section of late Llandovery age is that of the Cefn Cerig Road (transect d of Fig. 4), where almost continuous exposure extends through the Rhydings, Wormwood and lower part of the Cerig Formations and which includes (near the top of the Wormwood Formation) the type locality of the base of our revised Telychian Stage.

As can be seen from Table 5, the brachiopod faunas do not change greatly at the generic level during this period, apart from the local incoming of eospiriferids near the top of the Rhydings Formation and *Pentlandella* near the end of Llandovery time. However, the changes of most importance occur at the subgeneric, specific and subspecific levels. Two genera are paramount in these evolutionary studies: the pentameride *Stricklandia* and the rhynchonellide *Eocoelia*. In the Lower Llandovery *Stricklandia lens prima, S. lens lens* and *S.lens intermedia* are found (Williams 1951); in the Rhydings Formation and the Wormwood Formation *S. lens progressa* can be abundant, and in the Cerig Formation (e.g. at Loc. 163), the species *laevis* (previously known as *S. lens ultima*), which shows incipient ribbing, occurs. This stricklandiid lineage has been the subject of intense work since its original description by Williams (1951), and has been independently validated from Estonia (Rubel' 1977), Norway (Baarli & Johnson 1982), the U.S.A. (Amsden 1966, Johnson 1979): it is also known from many other areas in Britain and elsewhere.

Whilst *Stricklandia* is a very common fossil in the type Llandovery area, even finer subdivision may be achieved by the analysis of *Eocoelia*. Although Ziegler (1966) divided *Eocoelia* into successive species (of which *hemisphaerica* and *intermedia* occur in the Aeronian Stage, *curtisi* and *sulcata* in the Telychian Stage and *angelini* in the lower Wenlock Sheinwoodian Stage), in fact there is a progressive gradation in the stock in which both the ribbing characteristics and the articulation morphology change gradually with time; thus the species have arbitrarily-defined boundaries within a continuous spectrum. Fortunately, as recorded in Ziegler (1966: 530, 536) and confirmed by our recent collecting, *Eocoelia* is present in several localities in the type Llandovery area, and the progression from *E. hemisphaerica* through *E. intermedia* to *E. curtisi* can be traced in the southern part of the area in continuous sections with simple stratigraphy.

31

32

33

34

35

36

37A

37B

38

39A

39B

Figs 31–39 Brachiopods from the Aeronian Stage. Figs 31, 32, *Eocoelia intermedia* (Hall, 1860), Wormwood Formation; Fig. 31, internal mould of pedicle valve, BB 65426, ×3, Loc. 162; Fig. 32, internal mould of brachial valve, BB 38447, ×3, Loc. 170. Fig. 33, *Mendacella polygramma* (J. de C. Sowerby, 1839), internal mould of brachial valve; BB 35997, ×2; Rhydings Formation, Loc. 157. Fig. 34, *Glassia* aff. *tenella* Williams, 1951, internal mould of pedicle valve; BB 93861, ×3; Rhydings Formation, Loc. 109. Figs 35, 36, *Eopholidostrophia sefinensis* (Williams, 1951), Rhydings Formation, Loc. 169; Fig. 35, internal mould of pedicle valve, BB 93785, ×2; Fig. 36, external mould of conjoined valves, BB 95755, ×2. Fig. 37A, B, *Leptostrophia tenuis* Williams, 1951, respectively external and internal moulds of pedicle valve; BB 34541, ×2; Rhydings Formation, Loc. 169. Fig. 38, *Pentamerus oblongus* J. de C. Sowerby, 1839, internal mould of conjoined valves; BB 68565, ×1; Rhydings Formation, Loc. 14. Fig. 39A, B, *Stricklandia lens progressa* Williams, 1951, posterior and pedicle views respectively of internal mould of conjoined valves; B 5614, ×1·5 and ×1; Rhydings Formation, Loc. 168.

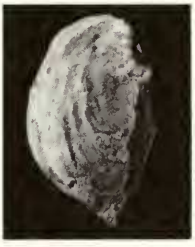
40

41

42

43A

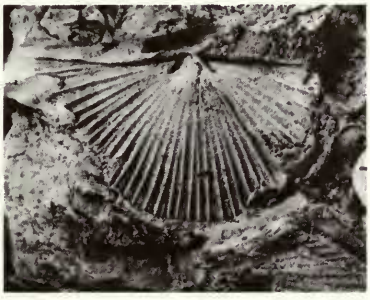
43B



44A

44B

45

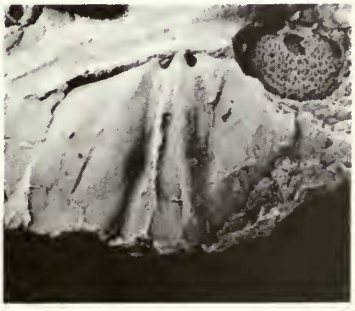


46

44C

47

48



49

Figs 40–49 Brachiopods from the Telychian Stage. All those illustrated come from the Cerig Formation, Loc. 163. Fig. 40, *Skenidioides lewisii* (Davidson, 1848), internal mould of brachial valve; BB 72818, ×4. Fig. 41, *Isorthis mackenziei* Boucot, Johnson, Harper & Walmsley, 1966, internal mould of brachial valve; BB 72767, ×2. Fig. 42, *Dicoelosia alticavata* (Whittard & Barker, 1950), internal mould of pedicle valve; BB 72786, ×3. Figs 43A, B, 45, *Eoplectodonta penkillensis* (Reed, 1917), internal moulds of pedicle valves; Figs 43A, B, BB 31776, ×2; Fig. 45, BB 31803, ×2·5. Figs 44A–C, *Clorinda globosa* (J. de C. Sowerby, 1839), internal mould of pedicle valve viewed laterally, posteriorly and from above; BB 73032, ×2. Fig. 46, *Coolinia applanata* (Salter, 1846), internal mould of pedicle valve; BB 72963, ×2. Fig. 47, *Atrypa orbicularis* J. de C. Sowerby, 1839, internal mould of pedicle valve; BB 72871, ×2. Figs 48, 49, *Eospirifer* aff. *radiatus* (J. de C. Sowerby, 1834); Fig. 48, internal mould of conjoined valves, BB 72927, ×2; Fig. 49, internal mould of brachial valve, BB 72908, ×3.

Table 5 Later Llandovery brachiopods and other macrofaunas from localities in the southern part of the Llandovery area.'××' denotes the abundant occurrence of crinoidal debris.

Formations	Rhydings					Wormwood				Cerig
Localities	168	169	109	156	157	170	161	162	187	163
Brachiopods										
Lingula spp.	–	6	–	–	–	–	–	–	–	1
Craniops implicatus	–	1	–	1	–	1	–	–	–	56
Orbiculoidea sp.	–	3	–	–	–	–	1	–	–	–
Dolerorthis psygma	2	–	–	–	–	11	1	1	–	–
Hesperorthis sp.	–	–	–	2	–	7	–	–	–	3
Giraldiella protensa	–	47	–	–	–	1	–	–	–	–
Skenidioides lewisii	1	–	–	1	1	14	8	2	39	80
indet. orthaceans	–	1	–	1	–	–	–	–	–	–
Isorthis beechhillensis	15	34	–	–	–	–	–	–	–	–
Isorthis mackenziei	–	–	–	–	–	–	–	–	17	7
Isorthis sp.	–	–	–	18	7	18	7	–	–	–
Resserella sefinensis	6	23	–	–	–	–	–	–	–	–
Resserella sp.	–	–	32	22	15	55	12	13	–	53
Visbyella pygmaea	–	2	–	–	–	–	–	–	42	17
Mendacella sp.	–	–	–	–	1	–	–	1	–	–
Dicoelosia alticavata	–	–	–	46	114	–	10	–	17	80
Triplesia sp.	2	–	–	–	–	1	–	–	–	–
Streptis sp.	–	–	–	–	–	–	–	–	–	5
Leangella scissa	2	26	6	–	1	–	–	–	–	–
Leangella segmentum	–	–	–	–	–	65	30	7	43	–
Eoplectodonta penkillensis	–	14	34	–	6	133	63	20	77	232
Ygerodiscus undulatus	3	–	–	2	–	–	–	–	–	–
Aegiria grayi	–	–	10	10	20	21	–	–	5	–
Katastrophomena penkillensis	1	1	–	1	1	–	2	1	1	–
Pentlandina parva	–	–	–	–	–	–	2	–	–	5
Leptaena purpurea	–	–	–	1	–	3	1	–	–	17
Leptaena urbana	–	–	–	–	–	–	–	1	3	–
Leptaena valida	–	11	–	–	–	–	–	–	–	–
Leptaena sp.	–	–	1	–	1	–	–	–	–	–
Cyphomenoidea wisgoriensis	–	–	–	–	–	1	–	–	–	–
Eostropheodonta sp.	–	2	–	1	–	–	–	–	–	–
Leptostrophia compressa	–	–	–	–	–	2	–	–	–	17
Leptostrophia tenuis	–	130	–	–	–	–	–	–	–	–
Eopholidostrophia sefinensis	–	177	–	–	–	–	–	–	–	–
Mesopholidostrophia salopiensis	–	–	1	5	6	4	5	3	3	49
Coolinia applanata	–	5	–	–	–	79	1	12	5	82
Parastrophinella? sp.	–	–	–	1	–	1	–	–	–	–
Stricklandia laevis	–	–	–	–	–	–	–	–	–	1
Stricklandia lens progressa	168	–	–	–	6	9	1	2	–	–
Pentamerus oblongus	–	–	–	–	–	21	–	7	1	–
Clorinda globosa	–	–	11	–	1	54	4	10	13	332
Rostricellula? sp.	–	1	–	–	–	–	–	–	–	–
Stegerhynchus sp.	–	1	–	–	–	8	–	–	–	–
Sphaerirhynchia sp.	–	–	–	–	–	–	–	–	–	2
Eocoelia hemisphaerica	–	43	–	–	–	–	–	–	–	–
Eocoelia intermedia	–	–	–	–	2	11	3	2	–	–
Eocoelia curtisi	–	–	–	–	–	–	–	–	–	3
Pentlandella pentlandica	–	–	–	–	–	–	–	–	1	2
Atrypa orbicularis	–	–	1	4	–	32	1	5	5	113
Protatrypa sp.	–	–	–	–	1	–	–	–	–	12
Eospirigerina sp.	–	5	–	–	–	–	–	–	–	–

Table 5 – *continued*

Formations	Rhydings					Wormwood				Cerig
Localities	168	169	109	156	157	170	161	162	187	163
Glassia? sp.	–	–	22	5	2	13	5	–	4	31
Meifodia ovalis	–	1	–	–	–	–	1	–	–	–
Eospirifer aff. *radiatus*	–	–	–	8	–	–	–	2	2	93
Cyrtia aff. *exporrecta*	–	–	–	–	–	–	–	1	–	–
Total brachiopods	200	534	118	129	173	565	158	90	278	1293
Other phyla										
illaenid trilobite	–	–	–	–	–	–	1	–	–	–
encrinurid trilobites	–	–	–	–	–	9	5	1	5	2
odontopleurid trilobites	–	2	–	–	–	1	1	1	1	1
calymenid trilobites	–	4	–	1	–	2	–	1	–	–
other trilobites	–	–	–	–	1	–	–	–	4	–
heliolitid coral	–	–	–	–	–	–	–	1	–	–
halysitid corals	–	–	–	–	–	2	1	–	4	–
favositid corals	–	–	–	–	–	35	–	–	–	8
streptelasmatid corals	3	–	–	1	1	34	9	12	8	–
halloporan bryozoans	1	1	1	4	3	1	–	2	1	6
thin twig bryozoans	–	–	–	1	1	2	2	–	2	–
net bryozoans	–	–	–	1	1	–	–	–	3	1
encrusting bryozoans	–	–	–	–	–	8	–	–	1	11
bellerophont mollusc	–	1	–	–	–	–	–	–	–	–
various gastropods	–	8	–	2	1	1	1	–	–	1
various bivalves	–	–	–	–	–	–	–	–	1	1
orthoceratid cephalopod	–	–	–	–	–	–	–	–	1	–
'Tentaculites'	–	11	–	–	1	1	–	–	–	–
crinoid columnals &c.	–	××	–	–	×	××	××	××	×	××

In addition, the *Borealis–Pentamerus–Pentameroides* lineages (e.g. Mørk 1981, Baarli & Johnson 1982), the lineages of *Leptostrophia compressa* and other leptostrophiids (Cocks 1967), pholidostrophiines (Hurst 1974) and atrypides (e.g. Copper 1982) can be useful in correlation and local dating. All these forms are present in the type Llandovery at Llandovery, and some are included in the summary chart at the end of this paper (Fig. 69). Species authors can be found in Cocks (1978).

Other brachiopods recorded from the late Llandovery of Llandovery, but not found in the collections shown in Table 5, are *Lingula pseudoparallela, Lingula symondsii, Schizocrania* sp., *Philhedrella* sp., *Triplesia anticostiensis, Triplesia glabra, Brachyprion arenacea, Strophonella* (*Eostrophonella*) *davidsoni, Amphistrophia whittardi, Fardenia* sp., *Antirhynchonella* sp., *Stegerhynchus*? *neglectus, Stegerhynchus weaveri, Whitfieldella* sp., *Hindella*? *furcata, Atrypina* sp. and *Howellella anglica*. Other species are undoubtedly present, particularly of enteletaceans, rhynchonellids and atrypoids, but further taxonomic research is needed before they can be identified satisfactorily.

When analysing the ecology, the communities proposed by Ziegler, Cocks & Bambach (1968) can be identified in most of the late Llandovery assemblages. In general the base of the Rhydings Formation carries *Stricklandia* assemblages (including the type locality for *Stricklandia lens progressa*), but the beds above this in the Rhydings Formation yield progressively deeper-water faunas with *Clorinda* and its assemblage, until at about the Rhydings–Wormwood boundary the deepest-water shelly assemblages are reached, which include such forms as *Aegiria* and *Dicoelosia* as well as less common *Clorinda*. Higher in the Wormwood Formation there is a progressive shallowing to *Stricklandia* and *Pentamerus*

Community assemblages, but the top of the Wormwood Formation and the Cerig Formation show renewed deepening, with *Clorinda* Community assemblages and even deeper-water faunas with only occasional shelly fossils in the upper part of the Cerig Formation. Superimposed on this pattern is a relative shallowing to the assumed land areas to the south-east from the basin to the north-west, so that, for example, the later Llandovery Derwyddon Formation of the Pen-y-waun fault belt carries shallower-water assemblages than the contemporary Wormwood Formation at Crychan Forest (transect f on Fig. 4).

(d) Trilobites

Trilobite remains have been found in all of the newly-recognized formations except the Derwyddon Formation. This formation is only locally developed; the apparent absence of trilobites in it may be due to disarticulation and breakage of exoskeletons in the high energy conditions under which it was deposited.

The trilobites are almost always disarticulated. A few complete or nearly complete exoskeletons are known: two specimens of *Diacalymene* (one each from the basal part of the Coldbrook Formation and from the lower part of the Goleugoed Formation), near complete *Calymene, Encrinurus* and *Astroproetus* and an articulated anterior portion of a zeliskellinid from the upper part of the Rhydings Formation, and articulated *Stenopareia* from the Wormwood Formation. The remains are invariably preserved as internal and external moulds. The state of preservation varies greatly; it is usually adequate and sometimes excellent.

Twenty genera of trilobites are represented in collections made during the present work and the older collections – mainly the O. T. Jones Collection (Sedgwick Museum, Cambridge). Of these twenty, calymenids and *Encrinurus* in particular, with *Leonaspis* and *Acernaspis*, dominate numerically. The dominance of these forms is entirely what would be expected in the relatively shallow, inshore marine conditions in which these mainly clastic rocks were deposited. But few specific determinations have yet been made. It is hoped that in particular the material of *Leonaspis* and *Acernaspis* may provide correlations within the area, and possibly outside. Species of these two genera are well known in the Llandovery of Scotland, Scandinavia and Estonia. In the literature a few taxa have been described from the type Llandovery area.

The following list is of the species identified from our new formations.

Bronydd Formation. *Acernaspis* sp., *Diacalymene* sp., *Proetus* (*s.l.*) sp., *Platylichas*? sp.

Crychan Formation. *Acernaspis* sp., *Calymene* sp., *Encrinurus* sp., *Leonaspis* sp., *Stenopareia* sp.

Trefawr Formation. *Acernaspis* sp., *Calymene* sp., *Harpidella* sp., *Leonaspis* sp. (Fig. 55), *Proetus* (*s.l.*) sp.

Figs 50–58 Trilobites from the type Llandovery area (SM = Sedgwick Museum, Cambridge; NMW = National Museum of Wales). Fig. 50, *Stenopareia* sp., dorsal view of cephalon, thorax and fragment of pygidium, internal mould; SM A65278, ×0·6; Rhydings Formation, Loc. 169. Fig. 51, *Stenopareia* cf. *catathema* Howells, 1982, internal mould of thorax and pygidium; SM A65724, ×0·6; Wormwood Formation, Loc. 213. Fig. 52A–D, *Diacalymene* aff. *marginata* Shirley, 1936, palpebral, dorsal, pygidial and left lateral views respectively of complete internal mould; BM(NH) It.18900, ×1; Goleugoed Formation, Loc. 147. Figs 53A, B, 54, *Encrinurus* cf. *mullochensis* Reed, 1931, Rhydings Formation, Loc. 169; Fig. 53A, B, anterior and palpebral views of internal mould of cephalon; NMW 83.37G.1, ×2; Fig. 54, dorsal view of internal mould of thorax and pygidium, SM A65275, ×2. Fig. 55A, B, *Leonaspis* sp., dorsal views of internal mould of cranidium and thorax; SM A66106, ×2; Trefawr Formation, Loc. 114. Fig. 56A–C, *Calymene replicata* Shirley, 1936, dorsal, pygidial and left lateral views of complete internal mould; NMW 83.37G.2, ×2; Rhydings Formation, Loc. 169. Fig. 57, *Decoroproetus* sp. 2 of Owens (1973: 54), dorsal view of latex cast of external mould of complete specimen; SM A81488, ×3; Rhydings Formation, Loc. 169. Fig. 58, *Leonaspis* sp., dorsal view of internal mould of pygidium; NMW 83.37G.3, ×4; Rhydings Formation, Loc. 104.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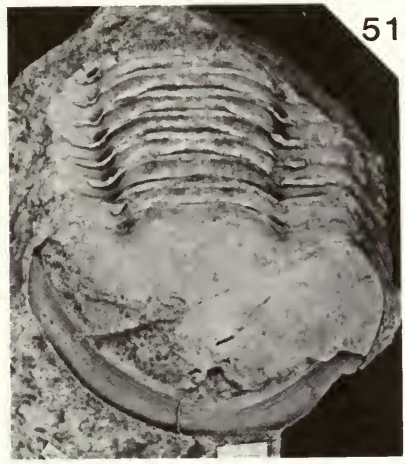
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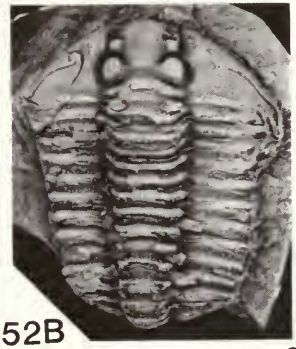
52A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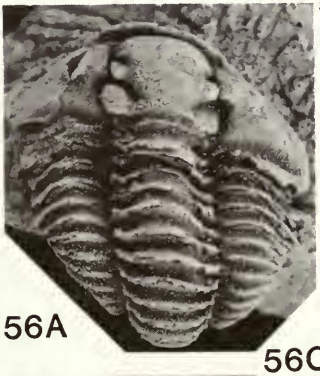
56A


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52D


56C


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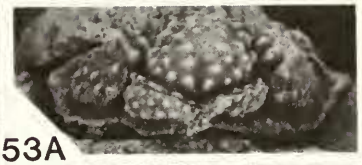
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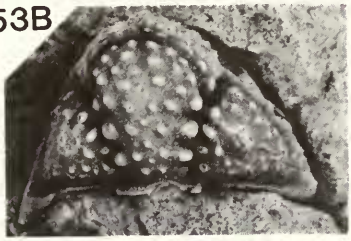
53B


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55A


55B


58

Coldbrook Formation. *Acernaspis* sp., *Encrinurus* sp., *Leonaspis* sp., *Diacalymene* aff. *marginata* Shirley.

Goleugoed Formation. *Diacalymene* aff. *marginata* Shirley (Fig. 52), *Encrinurus* sp., *Hadromeros*? sp., *Homalonotus* sp.

Rhydings Formation. *Acaste* sp., *Acernaspis* sp., *Astroproetus* aff. *scoticus* (Reed), *Encrinurus* cf. *mullochensis* Reed (Figs 53, 54), *Calymene replicata* Shirley (Fig. 56), *Decoroproetus* sp. 2 of Owens (1973: 54), *Hadromeros* cf. *elongatus* (Reed), *Homalonotus* sp., *Kosovopeltis* sp., *Leonaspis* sp. (Fig. 58), *Stenopareia* sp. (Fig. 50), zeliskellinid.

Wormwood Formation. *Acernaspis* sp., *Calymene* sp., *Decoroproetus* sp., *Encrinurus* sp., *Hadromeros* sp., *Leonaspis* sp., *Stenopareia* cf. *catathema* Howells (Fig. 51), zeliskellinid.

Cerig Formation. *Acernaspis* sp., *Calymene* sp., *Cheirurus* sp. A of Lane (1971: 17), '*Dalmanites*' sp., *Hadromeros* sp., *Youngia* sp.

(e) Molluscs

We have identified the following molluscs, with the help of Dr N. J. Morris of the Department of Palaeontology, BM(NH).

Goleugoed Formation. Bellerophontids: *Cyrtolites nodosus llandoveriana* Reed, *Grandostomus* aff. *dilatatus* (J. de C. Sowerby). Gastropods: *Lophospira* sp., *Liospira*? sp., *Gyronema*? sp., *Subulites* aff. *ventricosus* (Hall). Bivalves: *Cleionychia*? *mytilimeris* (Conrad). Cephalopods: *Trocholites planorbiformis* (Conrad), *Trochodictyoceras*? sp.

Bronydd Formation. Bellerophontid: *Kokenospira* sp.

Crychan Formation. Bellerophontid: *Cyrtolites* sp. Gastropods: *Gyronema octavia* (d'Orbigny, *sensu* Donald), *Lophospira* sp., gosseletininid. Cephalopod: *Trochoceras cornuariete* (J. de C. Sowerby).

Trefawr Formation. Bellerophontid: *Tropidodiscus* sp. Gastropods: *Loxonema*? sp., *Lophospira* sp. Pteriniid bivalve.

Rhydings Formation. Bellerophontids: *Grandostomus* sp., *Tropidodiscus* sp. Gastropods: *Pleurotomaria*? *pryceae* (J. de C. Sowerby), *Lophospira*? *angulata* (J. de C. Sowerby), *Holopella cancellata* (J. de C. Sowerby), *Phanerotrema* aff. *labrosum* (Hall), *Trochonema* sp., *Phanerotrema* sp., *Ruedemannia*? sp., *Raphistoma*? sp., *Cyclonema*? sp., platyceratid, holopaeacean, euomphalopterid. Bivalves: *Ctenodonta* sp., *Palaeoneilo* sp., *Actinodonta*? *hughesii* (Salter), *Cleionychia* sp. Cephalopod: *Phragmoceras pyriforme* (J. de C. Sowerby).

Wormwood Formation. Bellerophontid: *Bellerophon wenlockensis* (J. de C. Sowerby). Gastropods: turbiniform pleurotomariacean gen. nov., *Phanerotrema* sp., *Lophospira turrita* (Portlock), *Cyclonema tritorquatus* (M'Coy), holopaeacean. Cephalopods: *Cyrtoceras compressum* (J. de C. Sowerby), *Tretoceras*? *bisiphonatum* (J. de C. Sowerby).

Cerig Formation. Gastropod: *Planitrochus* sp.

Derwyddon Formation. Bellerophontid: *Kiaeromphalus* sp. Gastropods: *Gyronema* sp., *Phanerotrema*? sp. Cephalopods: *Actinoceras cochleatum* (Schlotheim), *Phragmoceras* sp.

It must be stressed that this is a provisional list; no substantial study of the molluscan fauna from the area has been made, although individual species have been described by J. de C. Sowerby *in* Murchison (1839), Blake (1882) and Reed (1920–21). In addition unidentified straight orthocone nautiloids are known from many localities in the area: Blake (1882) named four species.

(f) Other macrofossils

Both rugose and tabulate corals occur in the type Llandovery area and are abundant at some levels, but only very limited studies have yet been made of them. Dr D. Hill has identified the following from sectioned specimens. In addition we have collected a variety of specimens from many localities, but our field identifications are merely to genus group level.

Goleugoed Formation. *Streptelasma* cf. *araneum* (Smith), *S. crassiseptatum* Smith, *Plasmopora petalliformis* (Lonsdale).
Rhydings Formation. *Heliolites* cf. *parasiticus* Nicholson & Etheridge, *Calostylis* sp.
Wormwood Formation. *Favosites* sp., *Heliolites* sp., *Halysites* sp., *Pycnactis mitrata* (Schlotheim), *Calostylis* sp., *Phaulactis* sp., *Propora* cf. *magnifica* Počta.
Derwyddon Formation. *Halysites* sp., *Phaulactis* sp., *Lindstroemia* sp.

Bryozoans are also varied and abundant at many horizons but poorly studied, although Dr P. D. Taylor, BM(NH), has identified the commonest form in the Lower Llandovery as *Hallopora elegantula* (Hall).

Echinoderms are abundant in the form of crinoid ossicles; crinoid calyces are less common, but include glyptocrinids and cyclocrinids. Other groups occur sporadically, for example many specimens of the rhombiferan cystoid *Cheirocrinus* sp. were found in the Trefawr Formation at Loc. 151.

Receptaculitids and other sponges, hyolithids and also conulariids are all known as occasional specimens in the Goleugoed, Trefawr, Rhydings, Wormwood and Derwyddon Formations. Cricoconariids, informally identified as '*Tentaculites*' and '*Cornulites*', occur throughout the complete sequence.

(g) Microfossils

Acritarchs are abundant at most levels in the type Llandovery area and their distribution is described below (Appendix 1, p. 174); four main zones and a number of subzones can be recognized. Ostracods are rare in pre-Rhydings horizons, but can be abundant at some levels in the Upper Llandovery, although no work has been done on these from the type area. K. J. Dorning (personal communication) has collected chitinozoa and scolecodonts from the Goleugoed, Rhydings, Wormwood and Cerig Formations. They are present in moderate to low numbers in most palynological preparations, and are in general of moderate preservation. Outline investigations of the chitinozoa show they have some stratigraphical potential in the type Llandovery area. Conodonts are relatively scarce, but a limestone we collected from low in the Bronydd Formation (Loc. 92) was sent to R. J. Aldridge and I. Mohamed, who found in it the following conodonts: *Distomodus kentuckyensis* Branson & Branson, Pa, Pb, M and Sc elements; *Oulodus kentuckeyensis* (Branson & Branson), Pa and Sb elements; *Icriodella discreta* Pollock, Rexroad & Nicoll, Pa, Pb, M, Sb and Sc elements; and *Panderodus unicostatus* (Branson & Mehl), costate and simplexiform elements. This assemblage can be referred to the *Icriodella discreta–I. deflecta* Assemblage Zone in Britain, which spans a long interval from at or near the base of the Silurian to the early Upper Llandovery (Aldridge 1972).

Chronostratigraphy

(a) Stages within the Llandovery Series

In 1970, Cocks, Toghill and Ziegler proposed four stages, the Rhuddanian, Idwian, Fronian and Telychian, each with defined bases in the southern part of the type Llandovery area, apart from the base of the Rhuddanian which was defined at Dob's Linn, Scotland. There are two disadvantages of that classification. Firstly, the bases of the Idwian and Fronian (but not the Telychian) are in isolated outcrops, and secondly, it has been demonstrated by work subsequent to 1970 that the four stages are not of equal duration – the Idwian and Fronian appear shorter than the Rhuddanian and Telychian. The first disadvantage is in fact more theoretical than real, since the 'isolated' outcrops are parts of a simple stratigraphical sequence in the Ydw Valley which yields many fossils. However, it has been argued (and accepted by the Subcommision on Silurian Stratigraphy) that three stages for the Llandovery Series, rather than four, would make them of more comparable duration to those agreed for the Wenlock and Ludlow (although not for the Caradoc and Ashgill). Accordingly, we have taken advantage of our revision of the area to propose a three-stage system. The definitions of the stages are given below. The advantages of a new tripartite stage system are that the stages would be defined in continuously exposed fossiliferous sections, with a greater degree

Fig. 59 Aerial photograph showing a few of the forestry tracks in the northern Llandovery area, including the Trefawr track area of Fig. 60 (reproduced by permission of the Director of Aerial Photography, Cambridge University). Approximate scale 1:10,000.

of detailed control than the previous scheme; the Llandovery Series would be subdivided more equally than hitherto; and the correlation between shelly and graptolitic facies would be even more accurate in view of our graptolite finds near the limits of our new stages. In addition, as discussed below in the section on international correlation, the two points taken as stage boundaries are capable of very wide correlation. We take the bases of the upper two stages in the tripartite stage system at the base of the *triangulatus* Zone (which is the same as the base of the broader *gregarius* Zone) and at approximately the base of the *turriculatus* Zone. The last horizon, although new as a stage boundary within the Llandovery Series, was particularly welcomed at the Podolian meeting of the Silurian Subcommission since both the *turriculatus* Zone and the underlying *sedgwickii* Zone are very widely recognized internationally; this is in contrast to a stage boundary at the base of the *sedgwickii* Zone, which is difficult to recognize when the underlying *convolutus* Zone is not developed, as is the case in many places.

It should be noted that the new scheme disrupts the usage, unambiguous since the work of Murchison, of the term 'Upper Llandovery', although Murchison's 'Lower Llandovery' had already been redefined into a new 'Lower' and 'Middle' Llandovery by Jones (1925). Our new stage boundaries, although dividing Llandovery time more nearly equally into three parts, do not coincide with the Lower, Middle and Upper divisions of Jones.

However, one of us (JTT) dissents from the conclusions in this section of the report and considers that the most natural subdivision of the Llandovery Series, both at Llandovery and

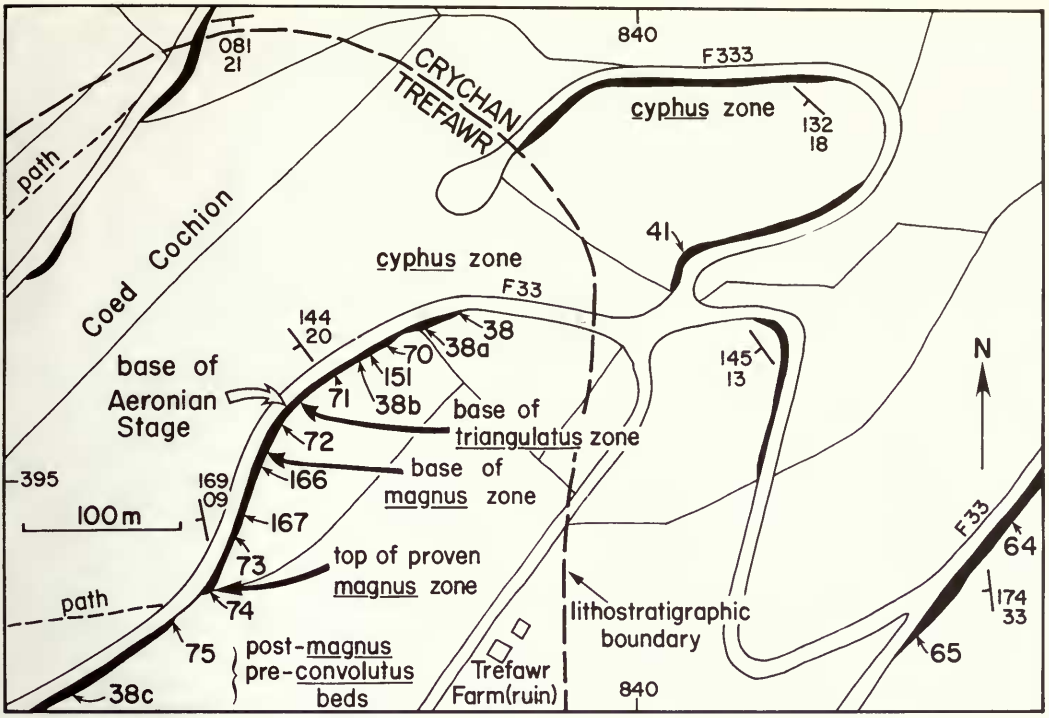

Fig. 60 Map of the base of the Aeronian Stage on the F 33 Trefawr track (transect h of Figs 3 and 4). Rock outcrops are shown in dense black: the larger numbers are our localities; the smaller numbers dips and strikes. Forestry Commission track numbers are preceded by F.

elsewhere, is into two stages, which can be widely recognized on both shelly and graptolitic faunas. In the Llandovery area a convenient base for an upper stage would be at Loc. 89 (transect h) on the Trefawr track, grid reference SN 8343 3923, which coincides approximately with the base of Jones' (1925) original C_1 division of the Upper Llandovery, and is mappable over most of the area. The basal beds of the upper stage yield *sedgwickii* Zone graptolites, a zone which is widely known internationally, and two important brachiopods characteristic of the higher part of the Llandovery (*Pentamerus oblongus* and *Eocoelia*) appear for the first time near to the base of the upper stage in the type area.

(b) The Rhuddanian Stage

The lowest stage may still be termed the Rhuddanian, but it is not considered fully here since its base is defined to be coincident with the Ordovician–Silurian boundary at the base of the *acuminatus* Zone at Dob's Linn, Scotland, rather than at the base of the *persculptus* Zone as originally defined by Cocks *et al.* (1970). The exact correlation of that horizon is not known in the type Llandovery area, but it is above the *Hirnantia*-bearing beds of the Scrach Formation and must be at or near the base of the Bronydd Formation. Its top is still at the same horizon as originally proposed, and there are many good developments of rocks and fossils representing the stage in the type Llandovery area, in particular the forestry track section near Scrach (transect i).

(c) The Aeronian Stage

We propose the new name Aeronian for this middle stage, named after Cwm-coed-Aeron Farm, 500 m south of the type section of the Trefawr track. Its base is defined at the base of the *triangulatus* Zone and the top is defined by the base of the revised Telychian Stage (see below). We considered two alternative bases to the Aeronian Stage, the base of the

Fig. 61 Stratotype base of the Aeronian Stage, Trefawr track, base of Loc. 72, Grid Reference SN 8380 3953, northern Llandovery area. The Trefawr track has continuous rock exposures for several hundred metres either side of this locality (see Figs 59 and 60).

triangulatus Zone as seen in transect h at the base of Loc. 72 (g.r. SN 8380 3953), or the base of the *magnus* Zone in the same section, the Trefawr track (Fig. 60) at the base of Loc. 166 (SN 8378 3950). The *magnus* fauna is the more widely recognizable within the Llandovery district itself, although the *triangulatus* Zone is recognized on three major sections, namely those of transects d, f and h. Both are recognized in the north and in the south of the type area, their bases being respectively within the Trefawr Formation and the Coldbrook Formation. However, the base of the *triangulatus* Zone has much the greater potential for international correlation either as the zone of this name or as the base of the broader *gregarius* Zone. Both depend upon the first appearance of triangulate monograptid species and the genera *Rastrites* and *Petalograptus*, and their bases are effectively coincident. The faunas have been identified on a more or less world-wide basis. For this reason we prefer to take the base of the Aeronian Stage at the base of the *triangulatus* Zone.

We define the base of the stage in a gently dipping section of blocky mudstones within the Trefawr Formation (Figs 61 and 62). The fauna is common, but dispersed throughout the rock and is only occasionally concentrated into shelly bands. Near the boundary the fauna consists chiefly of shelly fossils, mainly brachiopods (Fig. 63), but bivalves, gastropods, cephalopods, trilobites, rugose and tabulate corals, bryozoa, cystoids, tentaculitids and other phyla all occur in the macrofauna. Graptolites are also present at every horizon sampled, and the more important species are also shown in Fig. 63. The stage boundary is defined at the base of the *triangulatus* Zone, which is represented in the Trefawr section by the incoming of *Monograptus austerus sequens* Hutt. That this is effectively the base of the *triangulatus* Zone is demonstrated by the occurrence of *Monograptus austerus vulgaris*, the *cyphus* Zone ancestor of *sequens*, in the Trefawr section below at Loc. 70. The top of the *cyphus* Zone is also confirmed by the record of *Diplograptus elongatus* Churkin & Carter, which has never been recorded from above that zone.

Fig. 62 Stratotype base of the Aeronian Stage, enlarged detail of Fig. 61. The metre rule is parallel with the dip of the blocky mudstones. The actual base is at the base of the centimetre rule to the left of the metre rule.

On the neighbouring transect f, Loc. 100, at the same stratigraphical level as Loc. 72, yields *Monograptus* cf. *revolutus* Kurck, *s.s., Monograptus triangulatus* ? *separatus* Sudbury, *Monograptus triangulatus* ?*fimbriatus* (Nicholson), *Rhaphidograptus toernquisti* (Elles & Wood) and *Diplograptus* sp., which together also indicate the *triangulatus* Zone.

(d) The Telychian Stage

The highest stage will still be termed the Telychian, although its base is revised upwards from the base of the Wormwood Formation (Cocks *et al.* 1970: 83), the old C_4 division of Jones (1925), up to near the top of the Wormwood Formation, which allows much better international correlation. From our recent collecting we are able to confirm Ziegler's (1966) records of the rhynchonellid *Eocoelia intermedia* (Hall) in the upper part of the Rhydings and all through the Wormwood Formation, including Locs 162 and 162 on the Cefn Cerig Road section (Fig. 6, transect d). In the lowest parts of the overlying Cerig Formation (e.g. at Loc. 163) the earliest forms of the succeeding species *Eocoelia curtisi* are present, including specimens in which the umbonal chambers of *intermedia* and earlier forms are present only as relicts fused to the hinge line, indicating the point of transition between the two species, and we define the base of the Telychian at just above the highest record of true *intermedia*. This level is much more exactly correlatable than the previously defined base of the Telychian (Loc. 158 in the same Cefn Cerig Road section – Fig. 64).

The new base of the Telychian is defined in a quarry immediately west of the Cefn Cerig Road (Figs 64–66) at Grid Reference SN 7743 3232. The lithology consists of a series of siltstones with occasional sandy siltstones and muddy siltstones within the Wormwood Formation, which represents normal open shelf marine deposition without turbidites, with most of the beds bioturbated. Some shells occur in almost every bed, but a particularly

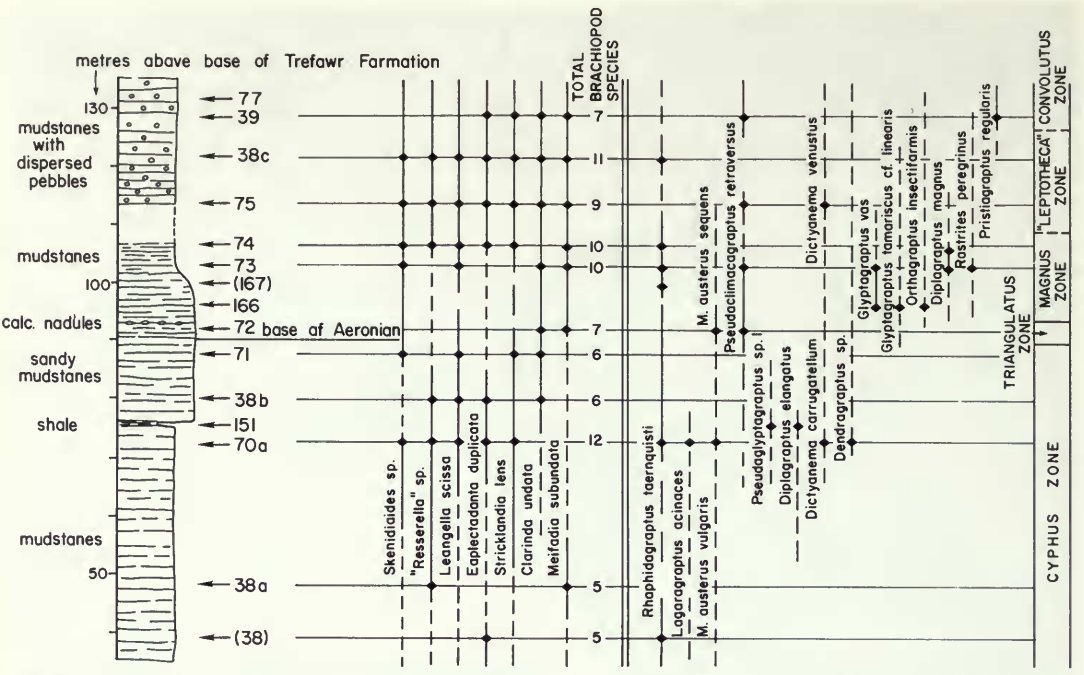

Fig. 63 Fauna of brachiopods and graptolites at selected intervals across the Rhuddanian–Aeronian boundary in the Trefawr track section. The locality numbers are shown on the left.

fossiliferous horizon (Loc. 162) just below the boundary (Fig. 67) yields 25 different species of macrofauna, many in abundance, and includes the highest records of the brachiopods *Eocoelia intermedia* (Hall) and *Stricklandia lens progressa* Williams, both widely recognized in international correlation (Ziegler 1966, Williams 1951 etc.). The succeeding species *Eocoelia curtisi* Ziegler and *Stricklandia laevis* (M'Coy) are both known from the overlying Loc. 163, and the stage boundary is defined here just above the last occurrence of *E. intermedia* at Loc. 162.

This horizon is widely recognizable and (at the limits of present stratigraphical precision) coincides with the base of the *turriculatus* graptolite zone; for a recent map of its distribution in Europe and eastern North America see Cocks & Fortey 1982: 473. Graptolites are not known from near the basal boundary of the Telychian in the Cefn Cerig Road section, but we have found a graptolite fauna referable to the *turriculatus* Zone at two localities in the Cerig Formation, one near the base of the formation at Loc. 131, transect n, yielding *Monograptus runcinatus* Tullberg: this graptolite is known world-wide and only from the lower half of the *turriculatus* Zone in the best documented sections. *Sedgwickii* Zone graptolites are known from a horizon over 400 m stratigraphically below the base of the revised Telychian. Thus the Aeronian–Telychian boundary probably correlates approximately with the lower boundary of the *turriculatus* Zone: this is confirmed by the distribution of the relevant *Eocoelia* species and graptolites in Penwhapple Glen, Girvan (Cocks & Toghill 1973). This horizon also correlates with the base of the Zone 4 acritarch fauna of Hill (1974 and see Appendix 1, p. 175), characterized by the incoming of *Deunffia monospinosa* Downie, *Domasia bispinosa* Downie and *Pterospermella* cf. *foveolata* Lister *in* Dorning (1981).

The basal Telychian Stage boundary is also to be found in the Glyn moch section (Fig. 4, transect f) at g.r. SN 8179 3755, which forms part of a continuously exposed section of over 400 m stratigraphical thickness in a Forestry Commission track. There, shells are common up

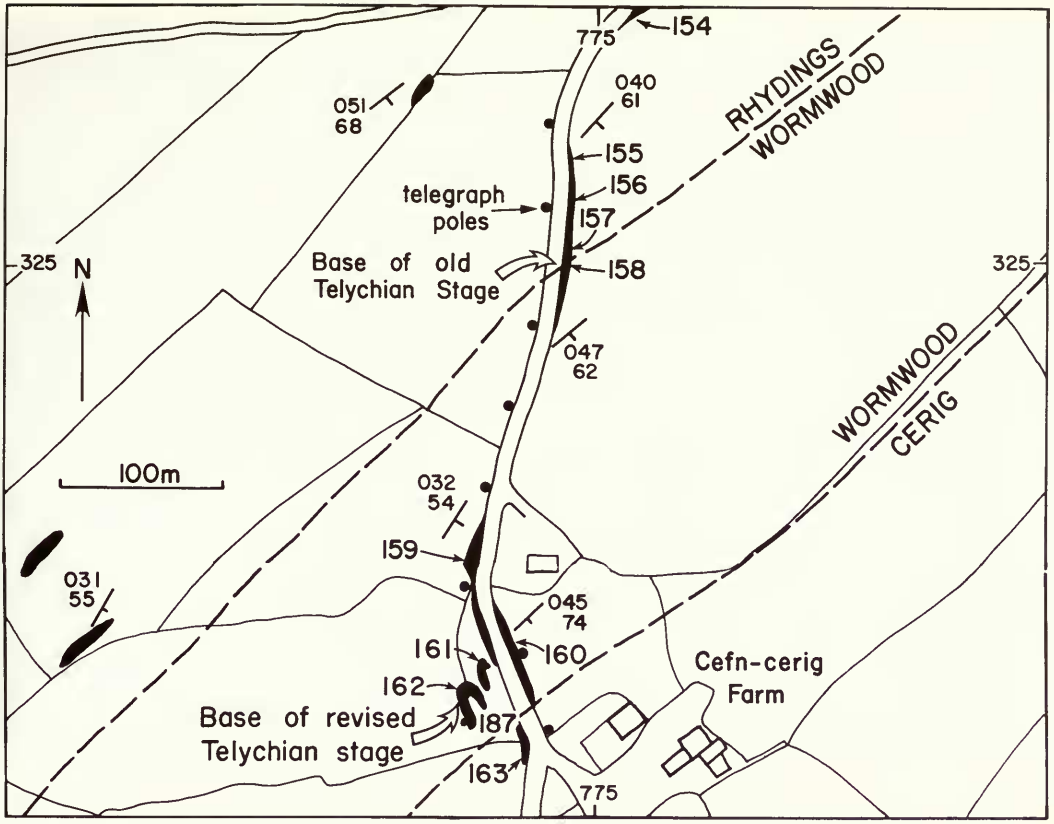

Fig. 64 Map of the base of the revised Telychian Stage on the Cefn Cerig road section (transect d of Figs 2 and 4).

to the top of the Wormwood Formation (Locs 5, 6), though sparser in the basal part of the Cerig Formation, but the overlying Loc. 140, 7m above the base of the Cerig Formation, carries a *turriculatus* Zone graptolite fauna. Although *Stricklandia* occurs in this section, the critical species of *Eocoelia* have not yet been found there.

International correlation

(a) Graptolites

It is probable that a complete sequence of graptolite zones exists in the type Llandovery area from the latest Ordovician to the *turriculatus* Zone of the upper Llandovery. Above this level graptolite zones are likely to be identified only on chance and rare finds. Below the *turriculatus* Zone graptolites are not uncommon, and provide relatively rich faunas in the Trefawr Formation. It has been possible to establish positively the presence of the *cyphus, triangulatus, magnus, convolutus, sedgwickii* and *turriculatus* Zones, probably the *acuminatus* level (though without rich faunas) and graptolitic strata almost certainly equivalent to the *persculptus, atavus, acinaces* and *leptotheca* Zones but which have yet to yield definitive species in association with the more common and longer-ranging graptolites. All these zones can be correlated on an international basis. Indeed several new records for the United Kingdom reinforce an already strong correlative framework, and include *P.* (*M.*) *fidus* (or *pictus*) Koren' & Mikhailova and *D.* aff. *elongatus* Churkin & Carter. Figs 7, 19 and 68

Fig. 65 Stratotype base of the Telychian Stage, Loc. 162, Wormwood Formation, old quarry west of Cefn Cerig road, Grid Reference SN 7743 3232, southern Llandovery area. The exposure continues for 9 m to the left and 17 m to the right of the photograph, and is part of the Cefn Cerig road section (see Fig. 64).

summarize the occurrence of graptolites against the lithostratigraphic and suggested biostratigraphic sequences.

(b) Shelly fossils

International correlation of rocks of Llandovery age has been effected by many authors by the study of evolving lineages of brachiopods. Chief of these is *Stricklandia* (Williams 1951, Amsden 1966, Rubel' 1977, Johnson 1979, Baarli & Johnson 1982), whose species and subspecies have been widely identified in Europe, the U.S.S.R., North America and elsewhere. All of the subspecies recognized by Williams (1951) were originally described from the type Llandovery area, and all of the successive constituents of the lineage are known from there, apart from the highest (*Costistricklandia lirata*). However, despite the work of Bąarli and Johnson (1982) who measured successive samples of early Llandovery *Stricklandia* from the Oslo region, Norway, and who were able to separate *S. lens prima* from *S. lens lens* on measurements of their cardinalia, we are not able to confirm the separation of early Llandovery *Stricklandia* subspecies in our work, and merely show the stratigraphical position of Williams' type specimens of *S. lens prima, S. lens lens* and *S. lens intermedia* on our Fig. 69. In the upper part of the Llandovery successions, the evolution of *Eocoelia* (Ziegler 1966) has also been useful, and three successive species, *hemisphaerica, intermedia* and *curtisi* are recorded from Llandovery. Pentamerinids, atrypids and some stropheodontaceans have also been used, and these are all known from the type Llandovery area. Thus the Llandovery type area can be correlated accurately with the many other Llandovery age rocks containing shelly fossils, both elsewhere in Britain and in key areas

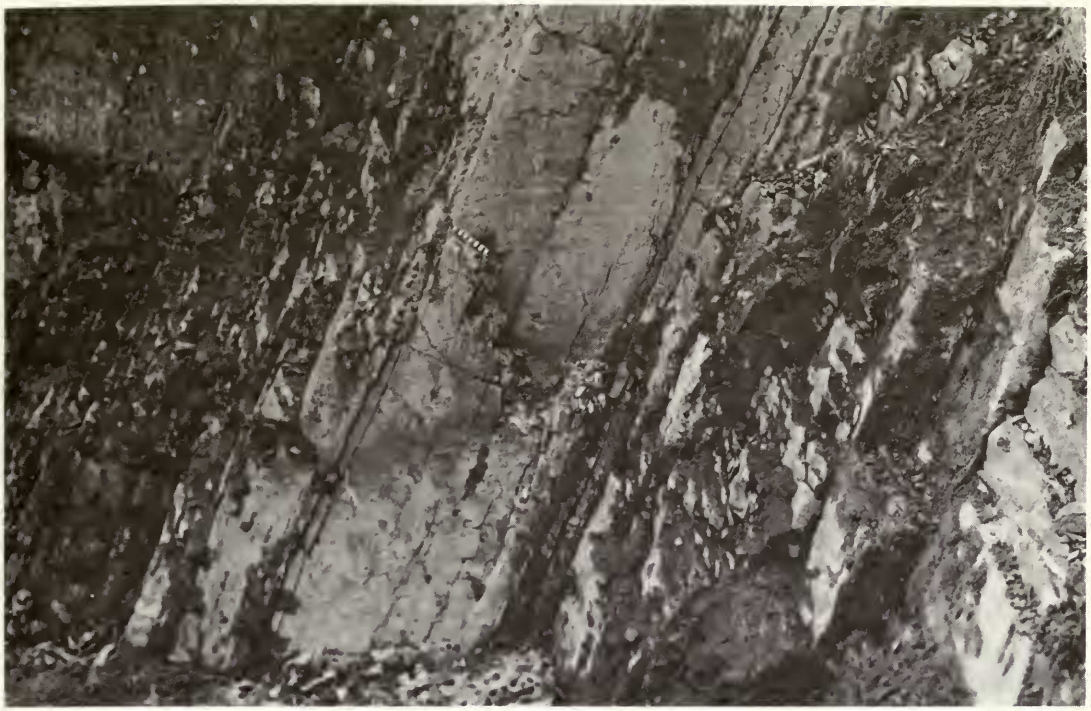

Fig. 66 Stratotype base of the revised Telychian Stage, enlarged detail of Fig. 65. The base is at the right hand end of the centimetre rule, within a 29 cm thick bioturbated shelf siltstone bed. The section youngs to the left of the photograph (the south).

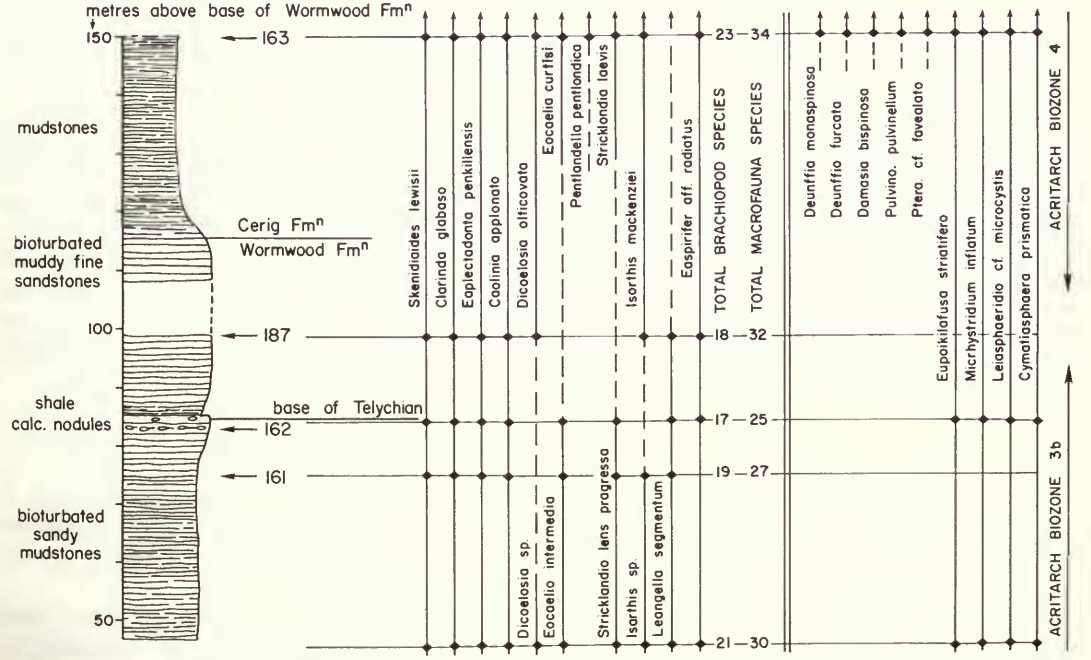

Fig. 67 Selected brachiopod and acritarch species across the Aeronian–Telychian stage boundary in the Cefn Cerig road section (transect d of Figs 2 and 4).

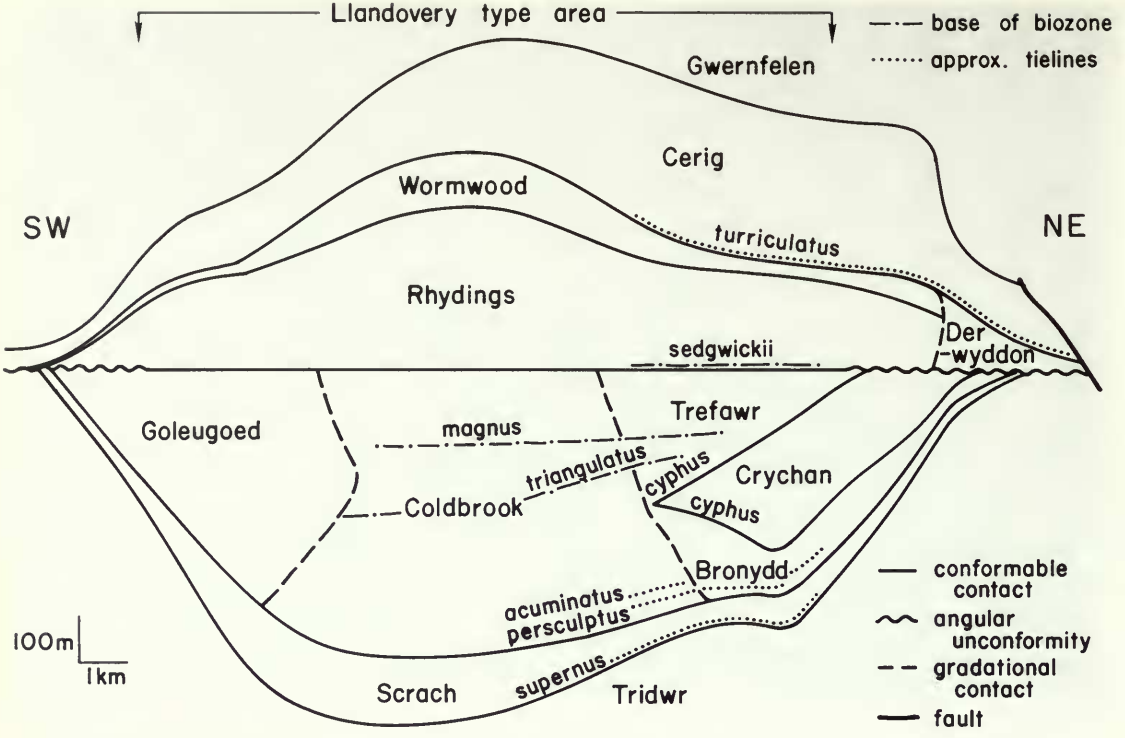

Fig. 68 Graptolite zones in relation to lithostratigraphy in the type Llandovery area.

abroad, including the Oslo region, Norway (Worsley 1982), and Anticosti Island, Canada (Barnes & McCracken 1981).

(c) Microfossils

No microfossil group is as yet very refined for the international correlation of rocks of Lower Silurian age. Only four conodont zones and four acritarch zones are established for the entire span of Llandovery time (by contrast to the 14 or more graptolite zones established for the same interval). Acritarchs are abundant in the type Llandovery area (see Appendix 1, p. 174), and reveal all the known zones (Hill 1974a); however, conodonts are relatively scarce, although the *Icriodella discreta–I. deflecta* Assemblage Zone is now known from our work in the Bronydd Formation. Chitinozoa and ostracods both occur in the type Llandovery area, but effective zonations have not yet been established for these groups in Britain or elsewhere.

Conclusions

1. Our new mapping has revealed that the development of rocks of Llandovery age is complete in the Llandovery type area: there is a continuous sequence from Ashgill through Llandovery to Wenlock age, with no detectable unconformities (except at the lateral flanks of the basin).
2. With the recent cutting of forestry tracks to add to the previous outcrops, there are long reaches of continuous exposure, providing adequate primary and confirmatory sections for collecting and research. Permanent access to the area and protection of the sections can be guaranteed through the Nature Conservancy.

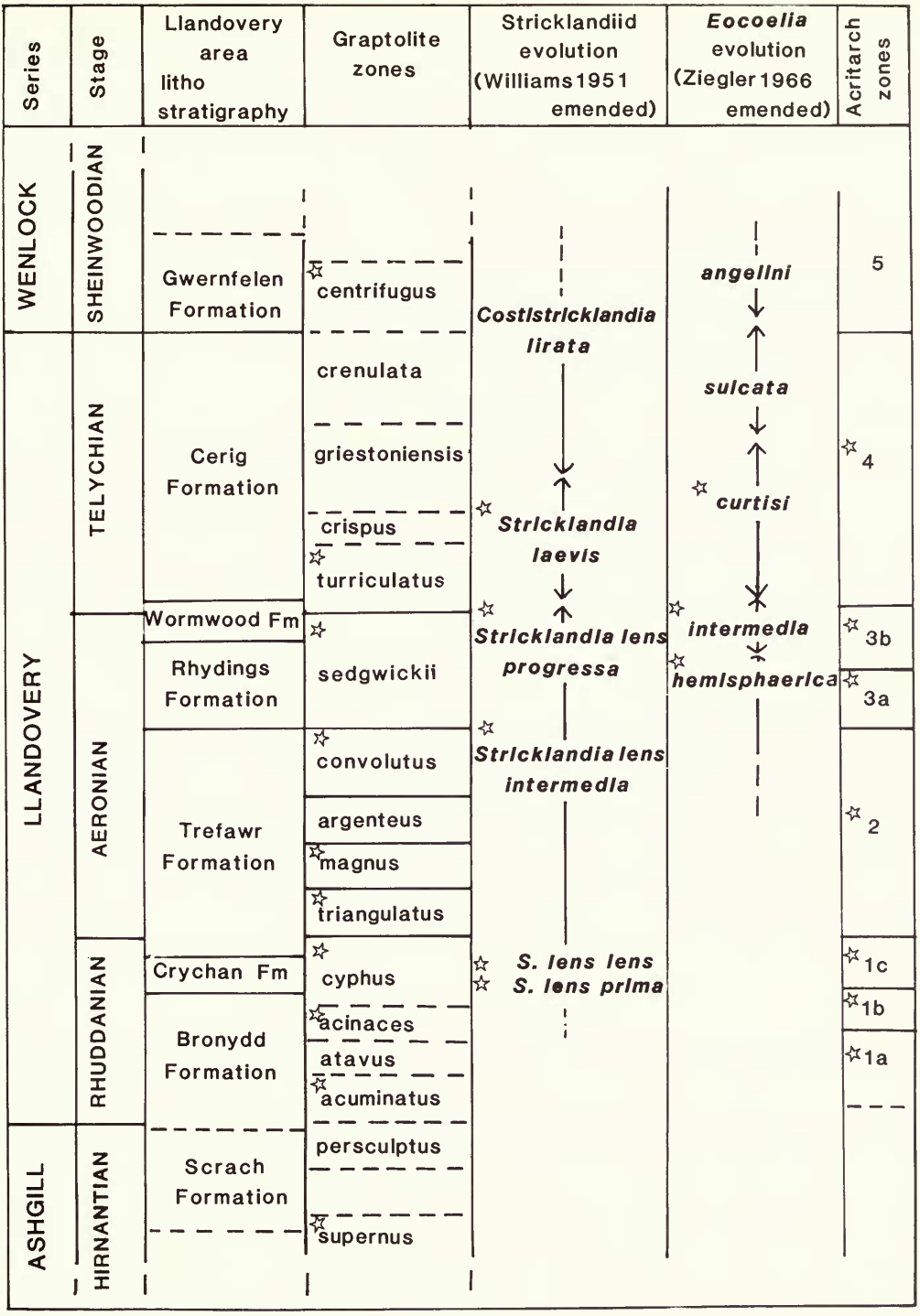

Fig. 69 Correlation of the Llandovery Series, showing our new lithostratigraphy and stage divisions, the standard scale of graptolite zones, the evolution of the brachiopods *Stricklandia* and *Eocoelia* and the acritarch zones of Hill (Appendix 1, p. 175). Zones and fossils with ☆ are known from the type Llandovery area.

3. The brachiopod faunas, including the important stricklandiids, pentameridines, *Eocoelia* and others, are abundant at numerous significant levels: to these we can now add the newly-discovered *Hirnantia* fauna from immediately beneath the type Llandovery. Trilobites, molluscs, echinoderms, corals, bryozoa and other shelly faunas also occur.
4. It is probable that a complete sequence of graptolite zones exists in the type Llandovery area from the latest Ordovician to the *turriculatus* Zone of the late Llandovery.
5. Substantial numbers of acritarchs from all levels have been demonstrated, including all the established zones, and some conodont faunas are also present, although only the *Icriodella discreta–I. deflecta* Assemblage Zone is yet confirmed.
6. The Llandovery area has been the international standard for rocks of Lower Silurian age since 1857. The good exposure and comprehensive faunas, both shelly and graptolitic, enables us to be in a position to define a three-stage division of the Llandovery Series in the type area, namely the Rhuddanian, Aeronian and Telychian, and the bases of the upper two stages are described in detail here.

Acknowledgements

We are most grateful to Amanda Chapman and Dr K. M. Evans for assistance in field work and laboratory, and to members of the Ludlow Research Group for other finds. Professor C. H. Holland and Dr M. G. Bassett also accompanied us on our initial field work. Dr M. A. Woollands generously made his unpublished thesis and maps available to us and Drs R. J. Aldridge, N. J. Morris, A. B. Smith and P. D. Taylor helpfully identified some of our collections. We also thank the Forestry Commission, through Mr I. Watt, who facilitated access to part of the area, and the Nature Conservancy Council, through Dr W. A. Wimbledon, who kindly arranged for the clearance of some localities.

Note

Following the circulation of a preliminary cyclostyled version of this paper, the Subcommission on Silurian Stratigraphy voted early in 1984 on the proposals suggested in this paper and on other matters, and in a Subcommission circular dated July 1984 it was announced that the Titular Members had voted in favour of the name Llandovery for the earliest series of the Silurian (by 14 votes to 1), and in favour of a three-stage system based on the type Llandovery area, namely the Rhuddanian, Aeronian and Telychian Stages as defined in the present paper (by 10 votes to 3, with 2 abstentions). These decisions were forwarded to the International Commission on Stratigraphy of the International Union of Geological Sciences for ratification.

Appendix 1. Acritarchs

by P. J. Hill (Division of Geology, Derby College of Higher Education, Kedleston Road, Derby DE3 1GB) & K. J. Dorning (Pallab Research, 58 Robertson Road, Sheffield S6 5DX).

Acritarchs have been recorded from all formations in the type Llandovery area. They are common to abundant in all samples apart from the sandstone facies of the Scrach Formation, where they are rare or absent. Preservation is variable, mostly good to moderate, occasionally poor. The moderate organic thermal maturation, indicated by the medium to dark brown coloration of the simple-walled acritarchs, is unlikely to have significantly affected the acritarch preservation.

62 different acritarch species have been recorded from the Llandovery area, as follows.

Ammonidium microcladum (Downie) Lister 1970, *A.* sp. 1 of Hill 1974 (numerous very short processes), *Baltisphaeridium archaicum* Cramer & Díez 1972, *Carminella maplewoodensis* Cramer 1968, *Cymatiosphaera prismatica* Deunff 1954, *Dactylofusa estillis* Cramer & Díez 1972, *Deunffia monospinosa* Downie 1960, *Dictyotidium dictyotum* (Eisenack) Eisenack 1955, *D. stenodictyum* Eisenack 1965, *Diexallophasis denticulata* (Stockmans & Willière) Loeblich 1970, *D. granulatispinosa* (Downie) Hill 1974, *Dilatisphaera dameryensis* Dorning 1981, *D. willierеae* (Martin) Lister 1970,

Domasia trispinosa Downie 1960, *D. bispinosa* Downie 1960, *D. limaciforme* (Stockmans & Willière) Cramer 1970, *Duvernaysphaera aranaides* Cramer 1964, *Electoriskos pogonius* Loeblich 1970, *Estiastra magna* Eisenack 1959, *Eupoikilofusa striatifera* (Cramer) Cramer 1970, *Helosphaeridium citrinipeltatum* (Cramer) Dorning 1981, *Leiofusa banderillae* Cramer 1964, *L. parvitatis* Loeblich 1970, *L.* cf. *tumida* Downie 1959, *Leiosphaeridia laevigata* Stockmans & Willière 1963, *L.* cf. *microcystis* (Eisenack) Downie 1959, *L. wenlockia* Downie 1959, *Lophosphaeridium* cf. *granulosum* (Staplin) Downie 1963, *L. parverarum* Stockmans & Willière 1963, *Metaleiofusa* sp. 1 (small elongate vesicle), *M.* sp. 2 (inflated vesicle), *M.* sp. 3 (very elongate vesicle), *Micrhystridium inflatum* (Downie) Lister 1970, *M. nanum* Deflandre 1945, *M. nannacanthum* Deflandre 1945, *M. parinconspicuum* Deflandre 1945, *M.* cf. *parinconspicuum, M. parveroquesi* Stockmans & Willière 1963, formgroup *M. stellatum* Deflandre 1945, *M.* cf. *vulgare* Stockmans & Willière 1962, *Multiplicisphaeridium arbusculum* Dorning 1981, *M. fisherii* (Cramer) Lister 1970, *M. imitatum* (Deflandre) Lister 1970, *M. micropilaris* (Cramer) Eisenack & Cramer 1973, *M. paraguaferum* (Cramer) Lister 1970, *M. rochesterensis* Cramer & Díez 1972, *Oppilatala* cf. *eoplanktonica* (Eisenack) Dorning 1981, *O. ramusculosa* (Deflandre) Dorning 1981, *Pterospermella* cf. *foveolata* Lister *in* Dorning 1981, *Pulvinosphaeridium pulvinellum* Eisenack 1954, *Salopidium granuliferum* (Downie) Dorning 1981, formgroup *Tunisphaeridium parvum* Deunff & Evitt 1968, *T. tentaculiferum* (Martin) Cramer 1970, *Tylotopalla robustispinosa* (Downie) Eisenack & Cramer 1973, *Veryhachium formosum* Stockmans & Willière 1960, *V. lairdii* (Deflandre) Deunff *ex* Downie 1959, *V. rhomboidium* Downie 1959, *V. scabratum* Cramer 1964, formgroup *V. trispinosum* (Eisenack) Cramer 1964, *V. valiente* Cramer 1964, *V. wenlockium* Downie 1959, *Visbysphaera meson* (Eisenack) Lister 1970.

Fifteen of the above species are long-ranging, and have been recorded in samples throughout most of the Rhuddanian, Aeronian and Telychian: *Ammonidium* sp. 1, *Diexallophasis denticulata, Leiofusa* cf. *tumida, Leiosphaeridia wenlockia, Lophosphaeridium* cf. *granulosum, L. parverarum, Metaleiofusa* sp. 2, *Micrhystridium nanum, M. parinconspicuum*, formgroup *M. stellatum, Oppilatala ramusculosa, Veryhachium rhomboidium*, formgroup *V. trispinosum*, and *V. wenlockium*.

Fig. 70 lists 45 species of restricted stratigraphical range in the southern Llandovery area. None of these are known from the Ashgill of the Llandovery area, while 14 are known to extend into the Wenlock in the Llandovery area. Additional data from the central and northern Llandovery areas, and other localities within the Welsh Basin, have shown many of the species to be similarly stratigraphically restricted. On the basis of all these data, seven acritarch assemblage biozones can be recognized in the Llandovery area, as follows.

Biozone 1a. Base of range of *Helosphaeridium citrinipeltatum. Baltisphaeridium archaicum* appears to be restricted to this zone. *Diexallophasis granulatispinosa, Dictyotidium dictyotum* and *Micrhystridium* cf. *parinconspicuum* have a base of range within this zone.

Biozone 1b. Base of range of *Metaleiofusa* sp. 1 and *Tylotopalla robustispinosa. Micrhystridium* cf. *parinconspicuum* is common.

Biozone 1c. Base of range of *Micrhystridium* cf. *vulgare* and *M. parveroquesi. Micrhystridium* cf. *parinconspicuum, Multiplicisphaeridium fisherii* and *Multiplicisphaeridium rochesterensis* are often recorded.

Biozone 2. Base of range of *Multiplicisphaeridium paraquaferum* and *Oppilatala* cf. *eoplanktonica. Tunisphaeridium tentaculiferum, Leiofusa banderillae* and *Domasia trispinosa* first occur within this zone. The base of biozone 2 is at about the base of the Rhydings Formation.

Biozone 3a. Base of range of *Domasia limaciforme, Metaleiofusa* sp. 3 and *Ammonidium microcladum. Leiofusa parvitatis, Multiplicisphaeridium arbusculum* and *Salopidium granuliferum* appear for the first time within this zone.

Biozone 3b. Base and top of range of *Dactylofusa estillis. Dilatisphaera williereae, Domasia limaciforme, Multiplicisphaeridium fisherii* and *Tunisphaeridium tentaculiferum* are frequently recorded.

Biozone 4. Base of range of *Deunffia monospinosa, D. furcata, Domasia bispinosa.* The base of biozone 4 approximates to the base of the Cerig Formation, the base of the redefined Telychian.

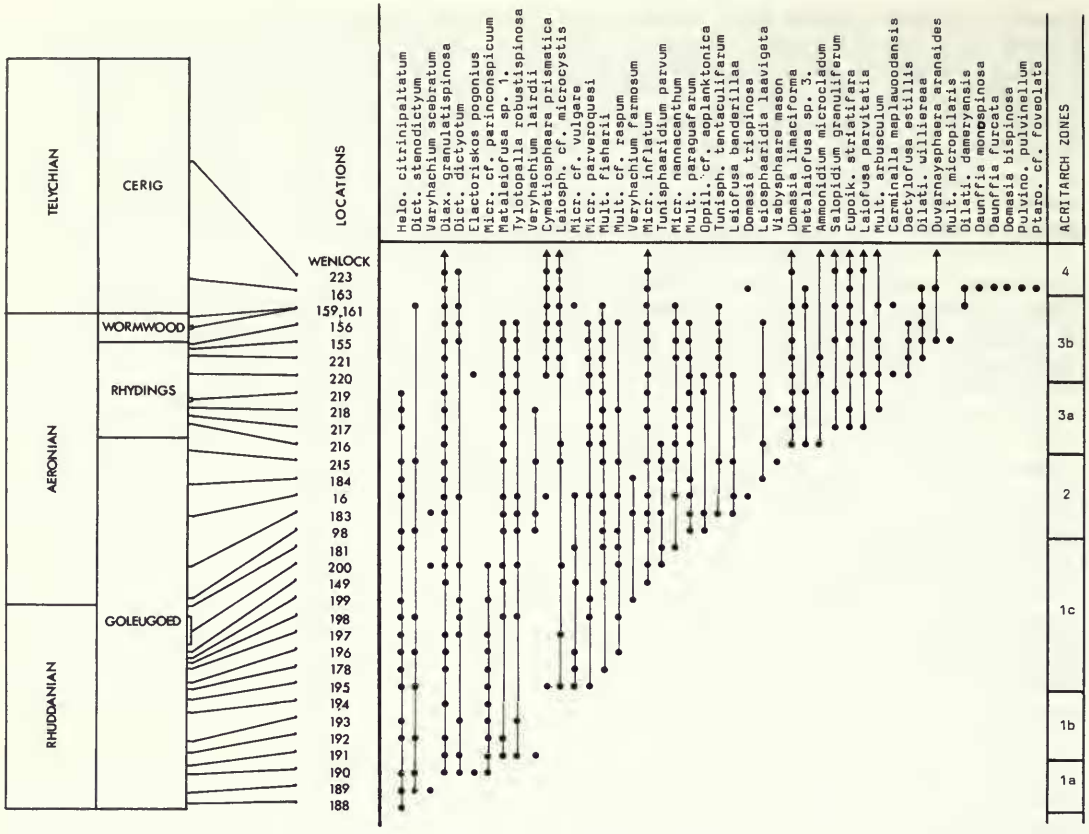

Fig. 70 Ranges of selected acritarch species in the type Llandovery area, chosen from the 62 species recorded, to illustrate the acritarch zones recognized (by P. J. Hill & K. J. Dorning).

The acritarch biozones recorded from the type Llandovery area can be recognized at many localities in Wales and the Welsh Borderland. Acritarchs characteristic of all the zones have been recognized from many localities in north-west Europe and eastern North America. However, acritarchs characteristic of the acritarch biozone W1 (Dorning 1981, = Zone 5 of Hill, 1974) which has a base 150 mm below the base of the type Wenlock at Leasows in Shropshire have not been recorded from the Cerig Formation.

Recycled acritarchs, dominated by forms of Tremadoc age, are present in many Rhuddanian and Aeronian samples. Of the total acritarchs, the recycled forms account for 4–10% in the lower Goleugoed Formation, 2–6% in the upper Goleugoed Formation, and fall to less than 1% in the Rhydings Formation.

Appendix 2. Llandovery district locality numbers

Formations are given as: Tr = Tridwr, S = Scrach, B = Bronydd, Cr = Crychan, Co = Coldbrook, Ce = Cerig, Go = Goleugoed, Gw = Gwernfelen, Tf = Trefawr, R = Rhydings, W = Wormwood, D = Derwyddon.

The eight-figure numbers shown are the National Grid References of Great Britain; they all lie within the SN 100-km grid square.

3 8164 3798 Tf
4 8158 3760 R
5a 8171 3751 R
5b 8172 3751 W
6 8181 3756 W
7 8207 3795 Ce
8 8484 3888 Tr
9 8450 3898 S
10 8450 3912 S
11 8425 3912 B
12 8410 3901 Cr
13 8374 3902 Tf
14 8340 3891 R
15 8299 3831 R
16 7601 3102 Go
17 8151 3732 R
18 8119 3738 Tf
19 8090 3729 Tf
20 8491 4111 S
21 8501 4079 S
22 8502 4048 S
23 8481 3999 S
24 8458 3964 S
25 8468 3961 S
26 8456 3955 B
27 8451 3953 B
28 8448 3952 Cr
29 8442 3949 B
30 8466 3924 S
31 8471 3920 Tr
32 8423 3950 Cr
33 8414 3941 Cr
34 8407 3928 Cr
35 8397 3907 Cr
36 8327 3929 Tf
37 8265 3909 Tf
38 8391 3960 Tf (= 38s)
38b 8383 3956 Tf
38c 8367 3940 Tf
39 8363 3937 Tf
39a 8356 3931 Tf (= 40)
40 8356 3931 Tf
41 8410 3963 Cr
42 8440 3982 Cr
43 8299 3826 R
44 8288 3809 R
45 8300 3809 R
46 8302 3775 R
47 8263 3777 W
48 836 377 Cr
49 8335 3728 Tf
50 8357 3717 Cr
51 8361 3724 Cr
52 8379 3788 Cr
53 8389 3808 Cr
54 8390 3815 Cr
55 8443 3863 S
56 8428 3861 B
57 8421 3814 S
58 8420 3780 Tr
59 8109 3812 Co
60 8116 3808 Co
61 8458 3956 B
62 8439 3951 Cr
63 8422 3949 Cr
64 8420 3948 Cr
65 8417 3944 Cr
66 8403 3920 Cr
67 8371 3898 Tf
68 8415 3966 Cr
69 8405 3972 Cr
70 8385 3958 Tf
71 8382 3950 Tf
72 8380 3953 Tf
73 8372 3943 Tf
74 8371 3943 Tf
75 8368 3940 Tf
76 8347 3925 Tf
77 8360 3934 Tf
78 8132 3839 S
79 8128 3836 Co
80 8127 3835 Co
81 8121 3832 Co
82 8121 3806 Co
83 8128 3805 Tf
84 8203 3822 Tf
85 8369 4045 B
86 8367 4028 B
87 8361 4082 Tr
88 8459 3957 B
89 8343 3920 R
90 8376 4059 S
91 8286 3954 B
92 8323 3975 B
93 8433 4017 Cr
94 7516 3003 Go
95 7544 2972 Go
96 7460 2984 Tr
97 7552 3102 Go
98 7568 3086 Go
99 7888 3485 Co
100 8207 3837 Tf
101 8147 3771 R
102 8162 3756 R
103 8163 3754 R
104 7823 3326 R
105 7829 3325 W
106 7863 3314 Gw
107 7846 3318 Ce
108 7846 3338 W
109 7820 3334 R
110 8470 3902 Tr
111 8473 3902 Tr
112 8447 3867 S
113 8339 3766 Tf
114 8352 3776 Tf
115 8365 3787 Cr
116 8412 3709 B
117 8410 3717 B
118 8491 3725 D
120 7604 3091 Go
121 7643 3046 W
122 7441 2819 W
123 8532 3850 Ce
124 8473 3715 B
125 8475 3715 B
126 8477 3713 Cr
127 8479 3712 D
128 8480 3711 D
129 8489 3702 Ce
130 8538 3843 D
131 8546 3841 Ce
132 8558 3839 Tr
133 8551 3839 Tr
134 8562 3836 D
135 8658 3880 Gw
136 8599 3845 Ce
137 8343 3887 R
138 8348 3887 R
139 8153 3764 R
140 8188 3764 Ce
141 7760 3328 Co
142 7759 3326 Co
143 7758 3323 Co
144 7760 3374 Co
145 7766 3357 Co
146 7767 3354 Co
147 7514 3191 Go
148 7516 3191 Go
149 7529 3192 Go
150 7515 3072 Go
151 8383 3957 Tf
152 7756 3279 R
153 7756 3277 R
154 7754 3271 R
155 7750 3265 R
156 7749 3260 R
157 7749 3255 R
158 7749 3255 W
159 7744 3241 W
160 7745 3239 W
161 7744 3235 W
162 7742 3233 W
163 7746 3229 Ce
164 7767 3352 Co
165 7679 3328 Co
166 8378 3950 Tf
167 8375 3946 Tf
168 7418 2817 R
169 7418 2812 R
170 7595 2957 W
171 7993 3547 W
172 8011 3564 W
173 8006 3568 W
174 8008 3553 W
175 8091 3703 R
176 8193 3777 W
177 8190 3790 R
178 7534 3086 Go
179 7546 3107 Go
180 7550 3117 Go
181 7566 3086 Go
182 7571 3091 Go
183 7582 3114 Go
184 7610 3126 Go
185 7435 2808 Gw
186 8420 3949 Cr
187 7743 3231 W
188 7455 3022 S
189 7591 3277 S
190 7764 3365 Co
191 7425 3080 Go
192 7443 3074 Go
193 7767 3345 Co
194 7563 3230 Go
195 7513 3042 Go
196 7522 3050 Go
197 7531 3088 Go
198 7540 3203 Go
199 7535 3191 Go
200 7534 3178 Go
201 8363 3895 Tf
202 8363 3895 Tf
203 8362 3894 Tf
204 8360 3894 Tf
205 8358 3893 Tf
206 8356 3892 Tf
207 8364 3896 Tf
208 8366 3896 Tf
209 8367 3896 Tf
210 8441 3952 Cr
211 8375 3904 Tf
212 8373 3900 Tf
213 8251 3704 W
214 7550 3117 Go
215 7612 3116 Go
216 7755 3302 R
217 7756 3300 R
218 7753 3295 R
219 7756 3291 R
220 7758 3285 R
221 7752 3268 R
222 7904 3369 Gw
223 7730 3187 Ce
224 8449 3953 Cr

Note – Other sample numbers with a or b are from the same localities as the corresponding number without letter.

Appendix 3. Grid references of logged sections of transects

All lie within the SN 100 km grid square, and they are also shown on Figs 2, 3, 4 and 6.

Transect	base	top	Remarks
a	7415 2828	7450 2825	outcrops in banks of River Sefin
b1	7462 2980	7463 2981	Forestry Commission track
b2	7495 3005	7445 2974	Forestry Commission track
c	7496 3067	7548 3096	natural outcrops and quarry sections in Ydw valley
d1	7757 3388	7760 3375	stream section
d2	7763 3368	7768 3353	stream section
d3	7760 3325	7747 3230	road section and abandoned quarries near top
d4	7847 3318	7848 3302	stream section
f1	8108 3813	8115 3808	Forestry Commission track
f2	8208 3838	8192 3811	Forestry Commission track
f3	8160 3756	8192 3765	Forestry Commission track
g	8367 4070	8352 4006	Forestry Commission track
h	8391 3960	8342 3921	Forestry Commission track
i1	8474 3904	8467 3901	Forestry Commission track
i2	8467 3962	8398 3912	Forestry Commission track
i3	8376 3906	8343 3887	Forestry Commission track
j1	8422 3818	8414 3804	Forestry Commission track
j2	8335 3763	8373 3795	Forestry Commission track
k	8410 3720	8416 3700	Forestry Commission track
l	8464 3720	8489 3700	Forestry Commission track
m	8492 3740	8498 3725	Forestry Commission track
n	8550 3838	8558 3823	Forestry Commission track

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Index

Fossils illustrated are shown in **bold type**. Question marks, 'aff.', 'cf.' etc. have been omitted from entries in this index.

Accepted for publication 22 May 1984